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Removal of Organic Contaminants from Drinking Water Supply at Glen Cove, New York. Phase I

Nebolsine Kohlmann Ruggiero Engineers
New York

Prepared for

Municipal Environmental Research Lab.
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16. ABSTRACT

This research program was initiated with the overall objective of obtaining relevant design parameters and capital and operating costs of both adsorption and aeration techniques for the removal of specific organic contaminants from the City of Glen Cove's drinking water supply. Major contaminants present are trichloroethylene, tetrachloroethylene, cis-1,2-dichloroethylene, and 1,1,1-trichloroethane.

A pilot plant was constructed and operated by using water from one of the city's contaminated wells and treating a portion of it via synthetic resin (Ambersorb XE-340) and diffused aeration. Resin depths of one foot, two feet, and four feet were used, and in most cases, virgin resin lowered the concentrations of all contaminants of concern to below 1 ug/L. Steam regeneration of the exhausted resin took place, but, although promising, the results achieved in the laboratory by the resin manufacturer could not be duplicated under pilot plant conditions. Aeration tests were conducted at air to water ratios of 30:1, 20:1, 15:1 and 5:1 and 60-95% removals were obtained.

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November 1980

REMOVAL OF ORGANIC CONTAMINANTS FROM DRINKING WATER SUPPLY AT GLEN COVE, N.Y.

Phase I

by

Dominick D. Ruggiero
Robert Ausubel
Nebolsine Kohlmann Ruggiero Engineers, P.C.
Consulting Engineers
New York, N.Y.

U.S. EPA Cooperative Agreement No. CR 806355-01

Project Officer

Walter A. Feige
Drinking Water Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
DRINKING WATER RESEARCH DIVISION
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communication link between the researcher and the user community.

The results of the first phase of a pilot plant study to remove organic contaminants from ground water are reported here. Synthetic resin adsorption with in-place steam regeneration and diffused aeration were the two treatment processes examined. The desired target level was shown to be an important consideration in interpretation of the data and in the choice of treatment technique.

Francis T. Mayo, Director
Municipal Environmental
Research Laboratory

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This report was submitted in fulfillment of Cooperative Agreement No. 806355-01 by Nebolsine Kohlmann Ruggiero Engineers, P.C. for the City of Glen Cove, N.Y. under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers the period March 28, 1979 to January 3, 1980 and covers phase one of the project. The second and final phase is scheduled for completion in early calendar year 1981.

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Mr. Eric Isacoff of Rohm and Haas Company was always available for advice about the resin. He also helped in conducting the regeneration attempts, and facilitated the transfer of information necessary in such projects.

We would also like to thank the Mayor of the City of Glen Cove and the Glen Cove Water Department, in particular, Anthony Caruso and Mrs. Margaret d'Esposito, as well as the men stationed at the test site.

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SECTION 1

INTRODUCTION

The City of Glen Cove, New York, located on the north shore of Nassau County, Long Island, receives its drinking water supply from a series of wells located throughout the City. Even though Long Island is part of New York State and parallels the southern coast of New England it is separated from the mainland by a salt water body, Long Island Sound. Therefore, the water supply to most of the communities on the Island is limited to wells since they do not have easy access to the watersheds on the mainland. Communities such as the City of Glen Cove, which depend on underground aquifers as the sole source of their water supplies, are greatly affected by contamination of these underground supplies.

The Glen Cove water supply system, which has a normal demand of approximately 3 million gallons per day (11,355 m^3/day) and 8 million gallons per day (30,280 m^3/day)during peak summer months, consisted of nine (9) wells designated as Duck Pond Rd. Wells Nos. 1 and 2, Seaman Rd. Wells Nos. 1 and 2, Morgan Island Well, Roxbury Well and Carney Street Wells Nos. 20, 21, and 22. These wells were capable of delivering more than an ample supply to meet peak requirements. However, analyses performed in the summer of 1977 by the Nassau County Department of Health, indicated that the water from Seaman Rd. Well No. 1 and Carney Street Wells Nos. 20, 21 and 22 contained trichloroethylene and tetrachloroethylene concentrations above New York State's maximum allowable limits of 50 micrograms per liter (ug/l) for any one organic contaminant and a total allowable limit of 100 ug/l for all such compounds. Therefore, the use of these wells was restricted by the County Health Department.

Faced with the problem of reduced water supply, the City of Glen Cove began evaluating methods to augment their reduced supply to a normal capacity level, and arranged to purchase water from adjoining communities until an adequate supply could be reestablished. To regain a sufficient supply of well water, the City decided on two approaches: the drilling of new wells in a non-contaminated area, and the definition of a treatment system which would render the water in contaminated wells usable.

The City retained the consulting engineering firm of Nebolsine Kohlmann Ruggiero Engineers, P.C. (NKRE) for the determination of a feasible and economical treatment system. Through consultation with the U.S. EPA's Drinking Water Research Division, Municipal Environmental Research Laboratory (MERL), Cincinnati, it was determined that no existing treatment system was capable of treating the large volumes of water containing these organic contaminants. After some preliminary testing of the Carney St. wells, discussions and negotiations between the City, NKRE and the U.S. EPA resulted in a research grant (later a cooperative agreement) funded by the U.S. EPA to test several possible treatment methods at the Glen Cove site.

The pilot plant testing program was conducted from March 28, 1979 to January 3, 1980 and consisted of the evaluations of synthetic resin and diffused aeration for the removal of organic contaminants present in Glen Cove's drinking water supply.

SECTION 2

CONCLUSIONS

RESIN ADSORPTION STUDIES

1. Test results using Rohm and Haas' Ambersorb XE-340 indicated that this resin was capable of reducing the levels of the contaminants to below existing New York State guidelines. In most cases, virgin resins achieved reduction of each contaminant to less than 1 ug/l, for the following influent concentration ranges: cis-1,2-dichloroethylene, 18-118 ug/l; trichloroethylene, 132-313 ug/l; 1,1,1-trichloroethane, 3-8 ug/l and tetrachloroethylene, 18-92 ug/l.

2. Generally, the order of breakthrough was cis-1,2-dichloroethylene, trichloroethylene, then tetrachloroethylene for empty bed contact times (EBCTs) of 1.9 and 3.8 minutes. Once the cis-compound broke through, it continued to leak at a much faster rate than the other compounds.

3. The target level is an important consideration in interpretation of the data. For an EBCT of 1.9 min., times in service to achieve an effluent level of 25 ug/l were: 65 days for the cis-compound, 108 days for trichloroethylene, and 170 days for tetrachloroethylene. However, if maintaining an effluent level of 5 ug/l, for example, is desired, the respective times become 40 days, 48 days, and 85 days.

4. The breakthrough and exhaustion of the resin occurred proportionately to depth for the one and two foot columns based on cis-1,2-dichloroethylene. This was not the case for all contaminants and therefore no true conclusion can be made as to the effect of bed depth.

5. Steam regeneration techniques require further testing before recommended techniques can be made. The testing of the methods of regenerating the resin did not produce a definite conclusion. While regeneration with steam appeared promising, the results achieved in the laboratory by the resin manufacturer could not be duplicated under pilot plant conditions. Contaminant breakthrough with

"regenerated" resin occurred much earlier than with virgin resin, probably because the regeneration had not been completely successful.

6. During this program, the Carney St. well operated almost continuously for a 250-day period. When pumping began, the contaminant levels were low, but increased steadily over the first 10 days. In subsequent days, although concentrations of the various contaminants varied, overall concentrations remained high.

7. The resin manufacturer's estimated capital costs of a full scale resin installation for plant capacities from 1-5 mgd (3,785-18,925 m^3/day) range from $420,000 to $1,200,000, based on two columns operating in series having an application rate of 4 gpm/ft^3 (0.42 lpm/m^3) on an empty bed contact time of 2 minutes. The estimated total annual operating cost, including amortization, is about $0.18-$0.31 per 1,000 gallons (3.79 m^3) of treated water. This cost is based on Glen Cove's comparatively high electrical costs, and may be lower in other areas. These costs do not include the cost of disposing and/or handling of the waste regenerant since no system for this has been demonstrated.

DIFFUSED AERATION STUDIES

1. Aeration reduced the tested contaminants below present New York State guidelines and to levels which might be acceptable throughout the nation. Thus far, air to water ratios of 30:1, 20:1, 15:1 and 5:1 have been investigated, and 60-95% removals of all compounds have been achieved. Once again, desired target levels must be defined before determining whether diffused aeration is a practical treatment process for Glen Cove. Presently the 50 ug/l New York State guideline may be achievable by aeration for each of the organics present at air:water ratio of 15:1, but if the guidelines were reduced to 10 ug/l, aeration by itself would be insufficient.

2. Diffused aeration, based on the test results to date, appears to be a viable treatment option for the removal of certain organic contaminants from groundwater.

3. The aeration system had no appreciable impact on contamination of the air and created no waste disposal problem.

4. Estimated capital costs of a full-scale aeration system for plant capacities from 1-5 mgd (3,785-18,925 m^3/day) range from $198,000-$633,000. The estimated total annual

operating cost including amortization is about $0.19-$0.28 per 1000 gallons (3.79 m^3) of treated water. This cost is based on Glen Cove's comparatively high electrical costs and may be lower in some areas.

SECTION 3

RECOMMENDATIONS

The pilot plant phase should be continued to establish proper design data and to make accurate economic evaluations from which to derive data for full-scale operations. Major research areas should be as follows:

ADSORPTION STUDIES

1. Test the resin system in both upflow and downflow modes of operation.

2. Improve the steam regeneration system to eliminate steam condensation and losses applying steam concurrently and countercurrently to flow. Investigate higher steam loadings.

3. Other solvents besides methanol should be examined and consideration given to the treatment or disposal of the condensate.

4. Determine actual electrical utilization for all equipment.

5. Install a granular activated carbon column to compare with the resin systems and determine the feasibility of regenerating granular activated carbon with steam.

6. Evaluate the resin system for its corrosive properties and the correct materials for construction.

AERATION STUDIES

7. Continue the diffused aeration testing and install and evaluate, for comparative purposes, a packed column aeration system and a small cooling tower.

SECTION 4

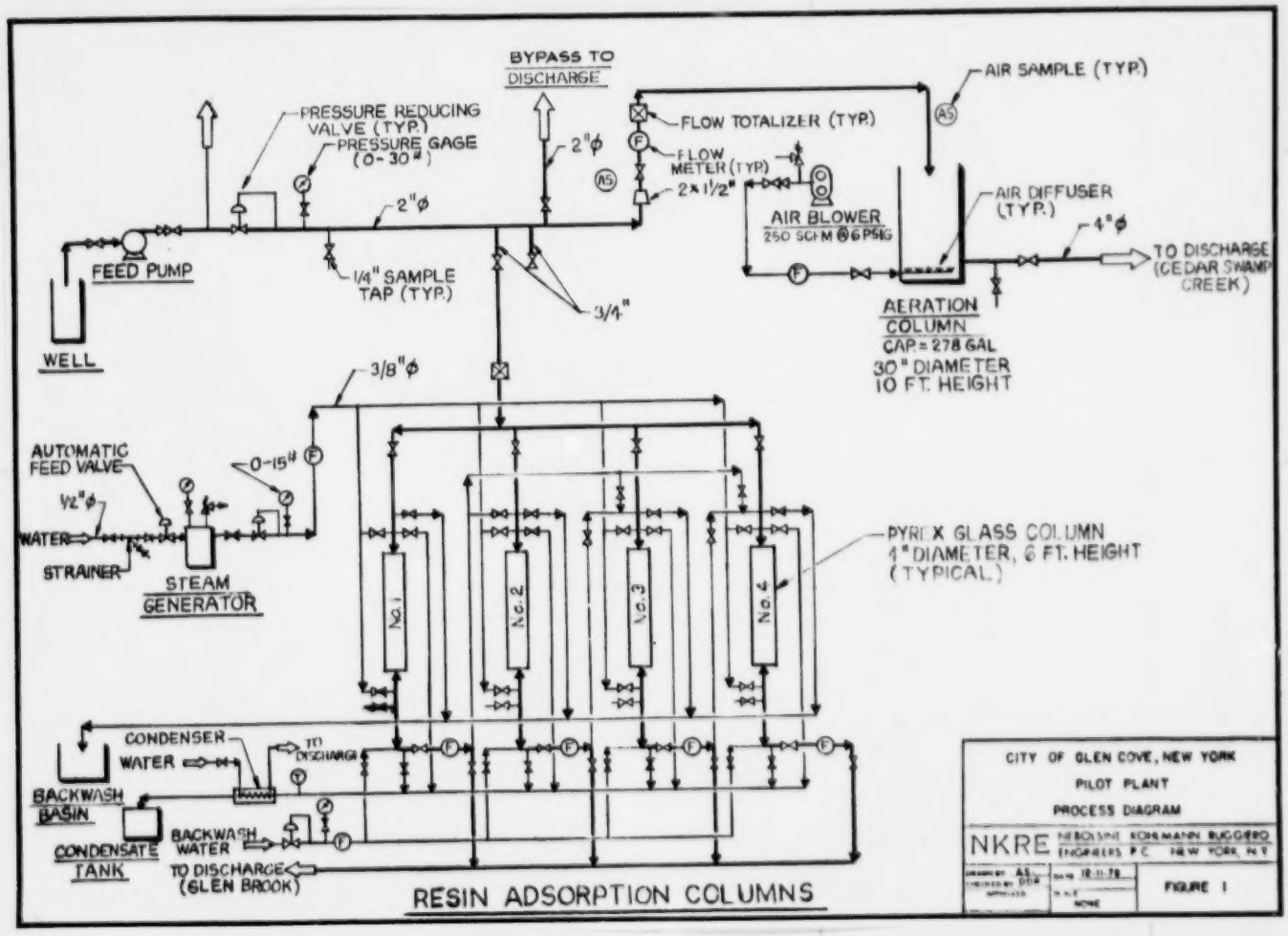
PILOT PLANT FACILITIES

Following the approval of the sub-contract with NKRE, the pilot plant was designed and the plans were reviewed with U.S. EPA (MERL-DWRD). It was decided that the systems to be tested should include diffused aeration in a countercurrent mode and adsorption using resin. A schematic flow diagram of the pilot plant facilities is presented in Figure 1.

Of the three wells at the Carney Street site, one with the highest concentration of contaminants, Well 22, was chosen for this testing program. This well draws water from an aquifer about 160 feet (49 m) below ground level. Its pump capacity is about two mgd (7570 m^3/day) and, since this is more water than is required for these tests, a major portion of the reduced well flow was discharged through a hydrant into Cedar Swamp Creek, which runs along the western edge of the Carney Street well field.

Since Well No. 22 is located at the eastern end of the well field near Highway 107, piping was installed to convey the water from the well head to the existing building which contained a portion of the pilot plant facilities. The effluent from the pilot plant facilities was conveyed to Cedar Swamp Creek. All piping had to be laid underground and under the access roads in the area because of the length of time that the pilot plant was to be operated. The installation of this piping took place during the winter, and unusually rainy weather caused delays in the installation of the pilot plant facilities. Construction of the pilot plant was completed by March 24, 1979, when operations began.

The pilot plant consisted of two separate operations or segments corresponding to the two methods being tested: resin adsorption and diffused aeration. Both systems were constructed and operated independently, using the same influent water from the well being tested. For the resin adsorption system, the water first flowed through a flow totalizer, then into a spiral wound nylon filter (which was added to the system at the end of May) and through the Pyrex glass columns containing the resin as shown in Figure 1. The columns were six feet high (1.83 m) and four inches (0.10 m) in diameter. Water flow


BYPASS TO DISCHARGE
AIR SAMPLE (TYP.)
PRESSURE REDUCING VALVE (TYP.)
PRESSURE GAGE (0-30#)
2"ϕ
FLOW TOTALIZER (TYP.)
FLOW METER (TYP.)
2x1½"
AIR BLOWER
250 SCFM @ 6 PSIG
AIR DIFFUSER (TYP.)
4"ϕ
TO DISCHARGE (CEDAR SWAMP CREEK)
FEED PUMP
1/4" SAMPLE TAP (TYP.)
3/4"
WELL
AERATION COLUMN
CAP = 278 GAL
30" DIAMETER
10 FT. HEIGHT
3/8"ϕ
AUTOMATIC FEED VALVE
0-15#
½"ϕ
WATER
STRAINER
STEAM GENERATOR
No.1
No.2
No.3
No.4
PYREX GLASS COLUMN
4" DIAMETER, 6 FT. HEIGHT
(TYPICAL)
CONDENSER WATER
TO DISCHARGE
BACKWASH BASIN
CONDENSATE TANK
BACKWASH WATER
TO DISCHARGE (GLEN BROOK)
RESIN ADSORPTION COLUMNS
CITY OF GLEN COVE, NEW YORK
PILOT PLANT
PROCESS DIAGRAM
NKRE NEBOLSINE KOHLMANN RUGGIERO ENGINEERS P.C. NEW YORK, N.Y.
FIGURE 1

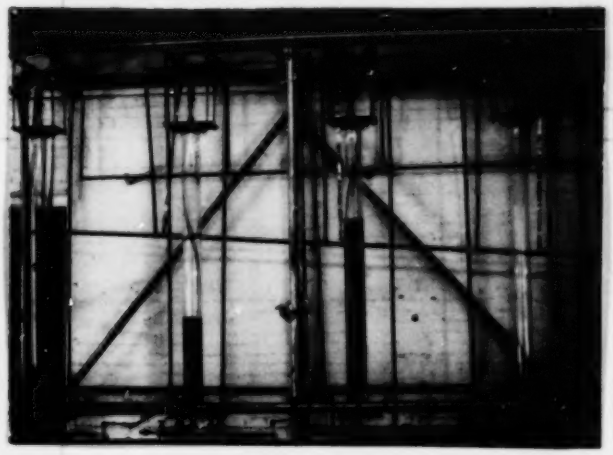
through the resin was in a downward mode. The arrangement of piping and valves allowed the columns to be operated in parallel and to be regenerated in either an upward or downward mode. In addition, City water was used to backwash the columns (rinse the resin with a counter flow of water). A Chromalox electric steam generator was provided to supply steam for periodic resin regeneration. Exhaust steam passed through a condenser on the steam discharge line, allowing the condensate to be collected.

The water to be treated by the second system, diffused aeration, flowed through an impact flow meter and a flow totalizer, both located inside the building, then to the acrylic aeration column, located outside and adjacent to the building. The test column was thirty (30) inches (0.76 m) in diameter and ten (10) feet (3.05 m) high. The influent water discharged at the top of the column and the water level was maintained at 8 feet (2.44 m) in the column. Water from the column discharged through a pipe attached about two feet (0.61 m) above ground. This effluent line was equipped with a sampling tap and a regulating valve. Effluent water from the aerator joined the effluent from the resin columns and both discharged into Cedar Swamp Creek.

Air for the aerator was supplied by a blower, and the flow was measured by a manometer. Air was diffused at the bottom of the column by five cylindrical diffusers. This arrangement resulted in the air flowing countercurrently to the water.

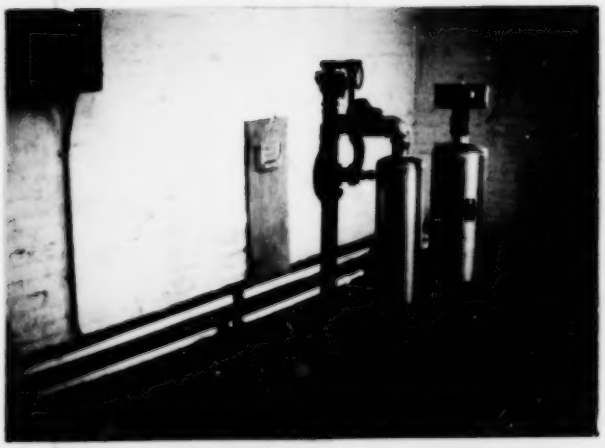
Included in the equipment purchased for the pilot plant testing program was the analytical instrumentation for measurement of the contaminants, including a Tracor gas chromatograph equipped with a halogen-specific, electrical conductivity detector and a Tekmar purge-and-trap concentrator. The gas chromatograph was also equipped with an automatic integrator which determined the area of a peak and printed out the results.

These testing units and analytical equipment are shown in the photographs presented in Figures 2 and 3.



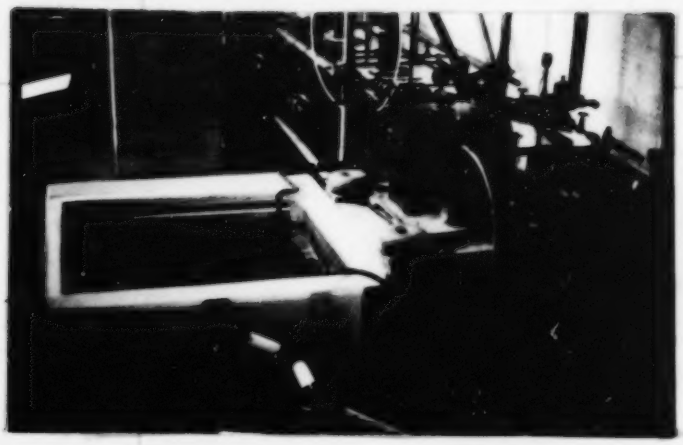
(a) Resin Columns

(b) Aerator column

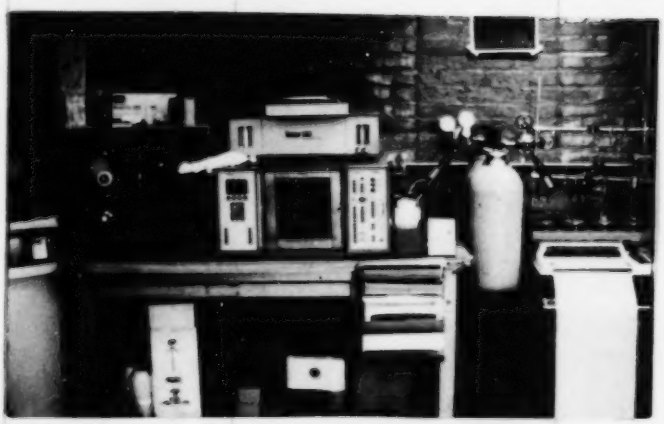


(c) Air Pump for Aerator. On the wall is the manometer which measures the air flow.

FIGURE 2



(a) Steam condenser and regenerator



(b) Analytical instrumentation

FIGURE 3

SECTION 5

TESTING PROGRAM AND OPERATION

The objectives of the testing program were the evaluation of the basic effects of resin adsorption and aeration on the removal of trichloroethylene, tetrachloroethylene, cis-1,2-dichloroethylene and 1,1,1-trichloroethane from the drinking water supply. The pilot plant program evaluated the aeration system using various air to water ratios while the resin adsorption testing used various bed depths, thereby providing varying contact times. Since resin generation would be required in an actual operating plant, the pilot plant program attempted to determine an appropriate method of regeneration.

The resin used was Rohm and Haas' Ambersorb XE-340 ® designed to remove relatively non-polar organic molecules and halogenated aliphatics from water. Based on laboratory studies carried out by the manufacturer, this resin was shown to be steam regenerable for many cycles. These laboratory studies were carried out on a surface water supply and tested primarily for the removal of chloroform. Only limited laboratory data were available on the steam regeneration of resin for the removal of trichloroethane and trichloroethylene.

Before putting the resin into use, it first must be hydrated. Were the resin not hydrated, its surfaces would repel water, making the adsorption or removal of the contaminants present in the water less efficient due to channeling. Hydrating the resin required soaking it in absolute methanol which generated heat and caused some bubbling. When this bubbling ceased, the hydration process was complete.

Initially three Pyrex glass columns were used, with resin depths of one foot, two feet and four feet, (0.30, 0.61, and 1.22 m) respectively, for Columns I, II and III. The flow through each column was set at 21 gallons/hr (0.08 m^3/hr), or 4 gpm/ft^2 adsorbent (0.42 lpm) as recommended by Rohm and Haas.

Samples of the common influent and the effluent from each of the three operating resin columns and from the aeration column were collected, Monday through Friday, during the first seven weeks of operation. During the first week of testing, the air blower for the aerator operated continuously.

Thereafter, due to the noise produced by the blower, and to save electricity, the blower operated only for two hours before sampling. During this period, over ten volumes of water passed through the aeration column to ensure thorough aeration prior to sample collection.

Water flow through the aeration column was set at 28 gal/min (6.4 m^3/hr), corresponding to a residence time of about ten minutes. The air:water ratio was varied by changing the air flow. A ratio of 30:1 was used for the first 12 sampling days. Then the ratio was lowered to 20:1. At the end of October, the ratio was set at 15:1. For the last three sampling days, a ratio of 5:1 was used.

Because the aeration process transfers contaminants from water to the air, it was necessary to determine if air pollution resulting from this process would be significant. An outside laboratory, Industrial Hygienics of Huntington, N.Y., was hired to sample and analyze the air around the aerator. On the day the sampling was done, the aerator was operating at a ratio of 15:1. Results of the analyses are presented in Appendix C.

After two and a half weeks of pilot plant operation, a reddish colored foreign matter, similar to rust, accumulated on top of all three resin columns. As operations proceeded, this foreign matter formed into a plate, resulting in a decreased flow of water through the resin.

When water flow through the resin bed decreased below 16 gph (1.0 l/min) on May 10, 1979, the flow was stopped and the 100 mesh screens, placed at both ends of all columns to retain the resin, were removed from the tops of the columns and were replaced with 50 mesh screens. The bottom screens were not replaced so as not to disturb the resin bed. The screens that were removed contained rust and a hydrous, almost gelatinous, translucent whitish mass. On exposure to air, this material dried to a white powder.

On May 25, after two months on line, Columns I and II had to be taken out of operation to remove the deposits on top of the resin which hindered flow at the desired rate. In an attempt to rid the columns of these rust plates, water was forced at the plates using a hose. Some pieces of the reddish plates were washed out through the top of the columns, although not all of the material could be removed and some of it was driven deeper into the resin beds.

To prevent accumulation of such material, a spiral wound nylon cartridge filter was installed in the influent line. When a pressure drop across the filter occurred, indicating filter blinding, the filter was replaced.

The same rinsing procedure was later repeated on Column III, and in both cases, when water flow was resumed through the column, the orange-red color reappeared above the resin bed.

By the beginning of June, exhaustion of Column I for cis-1,2-dichloroethylene was observed, and steam regeneration of the resin took place on June 21. Because the analytical equipment was not functioning properly at that time, the effectiveness of regeneration could not be determined. However, the recommended regeneration procedure, prescribed by Rohm and Haas, was followed, and is described in Section 7.

After regeneration, a fresh one-foot (0.30 m) depth of Ambersorb XE-340 was hydrated and placed in the remaining, unused Pyrex glass column, designated Column IV. The purpose for testing this new bed was to compare the performance of fresh resin with that of the recently regenerated resin.

From the end of June and until completion of the first phase of the testing program in January 1980, all four (4) resin columns were operated continuously, except for periods of regeneration and occurrences which are described in the following paragraphs.

Concurrent with the attempted regeneration of Column I in June, the well being used as a source of contaminated water supply was shut down for four days. This action was required by the Nassau County Board of Health to allow the U.S. Geological Survey team to determine the subterranean water flow in the area of Cedar Swamp Creek. After the well was turned on again, the water was analyzed to ensure that it was at previous pollution levels before pilot plant operations were continued.

After the first couple of months of pilot plant operation, an increasing problem in operating the filtration system was noticed when the flow rate of water through the columns gradually decreased. This was particularly true of the deeper resin beds, Columns II and III. Eventually, it became necessary to stop the water flow through the affected columns and backwash them. While backwashing, a rubber mallet was used on the columns to help free the air entrapped in the bed. Because the resin system was closed to the atmosphere, the air must have been contained in the well water.

On one occasion, the whole resin system suffered a drop in water flow. This was so severe that some of the columns were partially emptied of water. However, the water level remained higher than the resin bed level. The cause was traced to a restriction in the pressure reducing valve installed near the cartridge filters. One of the elements inside the valve had corroded to such an extent that water flow was severely

curtailed. Since the well water is not particularly acidic or high in metal ions, the cause of the corrosion may have been due to the air which was present in the well water.

By the beginning of August, another attempt was made to regenerate Column I. This time a greater volume of steam was used and more time was given to effect regeneration. Because of electrical problems with the steam generator, the regeneration did not take place until August 16 and 17. During this period, teflon plates were inserted between the aluminum plates and the screens to prevent further corrosion. This modification was performed only to the top aluminum plates and to the bottom plate on Column I, which was regenerated, so as not to disturb the resin beds.

Based on contaminant breakthrough, Column I again required regeneration by the end of October, as did Columns II and IV, both for the first time. It was decided to allow Column IV to continue operating to obtain more complete breakthrough curves. Column II was to be regenerated first, with the direction of steam flow to be concurrent with the normal water flow. Then Column I would be regenerated with the steam injected countercurrent to the normal water flow. At the recommendation of Rohm and Haas, both the original 11 lb/hr (4.99 kg/hr) steam generator, and a new 20 lb/hr (9.07 kg/hr) generator were used in parallel.

Regeneration of Column II was begun on October 30 and continued for 26 hours over a three-day period. When the process was completed, a teflon plate was placed over the lower aluminum plate and a 50-mesh screen was installed at the bottom of the column. Regeneration of Column I began on November 5. However, because of poor results due to condensate accumulation, the attempt at upwards regeneration was abandoned after two days. Because the attempt at upward regeneration with steam was unsuccessful, regeneration with methanol was attempted on Column I and was completed in one day.

Each column was returned to operation after regeneration was completed and the pilot plant was operated until January 3, 1980.

SECTION 6

RESULTS

ADSORPTION STUDIES

The performance of the three resin bed depths as a function of service time is shown in Figures 4 through 7 for the four organic contaminants present in the Glen Cove water supply (individual data appear in Appendix B). These graphs chart the contaminant concentrations in the effluents until the column was first regenerated and compare them to those of the influent. No Column I effluent is shown for 1,1,1-trichloroethane because monitoring for this compound did not take place until after Column I was regenerated.

It is believed that fluctuations in the effluent are a result of air-binding, which resulted in channeling of the water flow. The air-binding may have been caused by air coming out of solution as a result of lower pressure at the well head, or by the shutting off of the air check valves.

Based on the pilot plant results thus far, cis-1.2-dichloroethylene was the first compound to saturate the resin. A comparison of the performance of the one and two foot (0.30 and 0.61 m 0.61 m) columns presented in Figure 4 showed that breakthrough and exhaustion occurred proportionately - breakthrough at about 50 days vs. 100 days, and exhaustion at about 70 days vs. 150 days. This relationship did not hold for the four-foot (1.22 m) column, Column III, which began leaking cis-1,2-dichloroethylene at about the same time as Column II. However, only about half as much contaminant was present in the Column III effluent and exhaustion was not observed. The reason for this "earlier than expected" breakthrough may have been channeling. Not only was air-binding a problem, particularly for Column III, but so was sedimentation of extraneous material formed on the upper surface of the resin. These particles lodged in the body of the resin bed while the resin was being backwashed to release air.

Because the resin had least affinity for cis-1,2-dichloroethylene, it was considered the best compound for studying breakthrough characteristics, especially since much longer service times were needed for the other pollutants in the water.

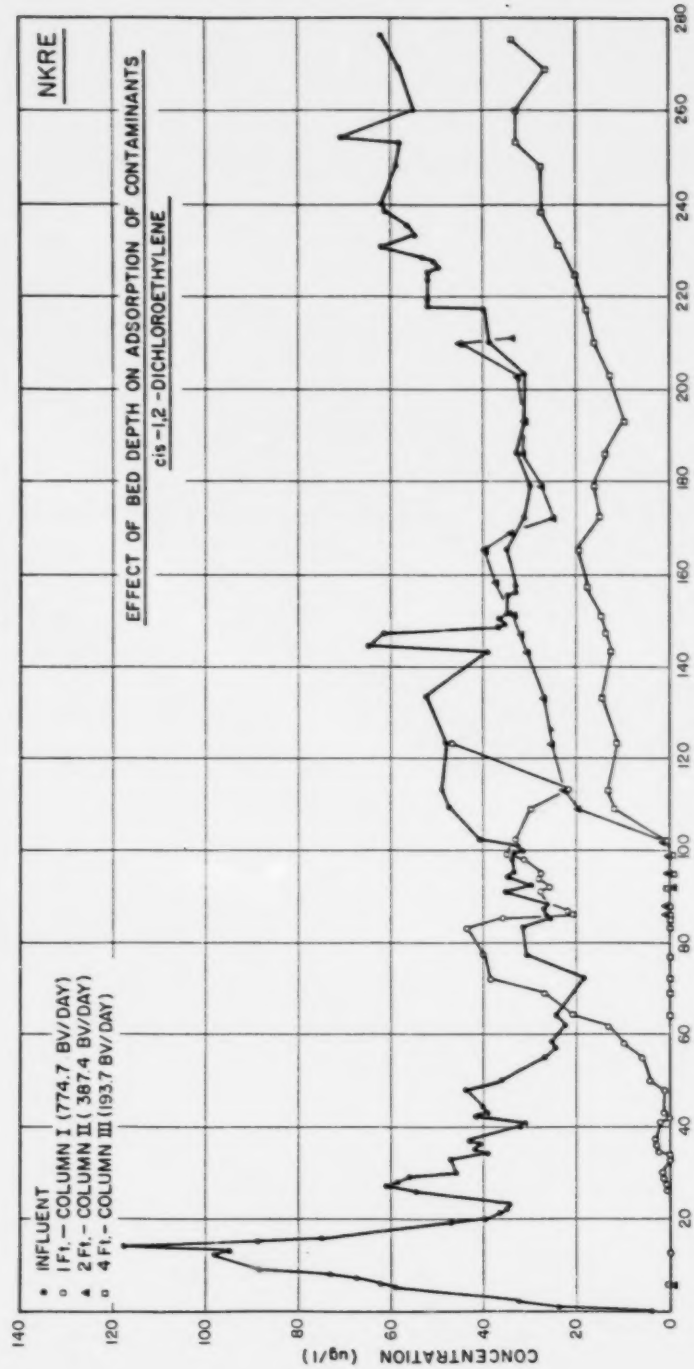

NKRE
EFFECT OF BED DEPTH ON ADSORPTION OF CONTAMINANTS
cis-1,2-DICHLOROETHYLENE
• INFLUENT
○ 1 Ft. – COLUMN I (774.7 BV/DAY)
▲ 2 Ft. – COLUMN II (387.4 BV/DAY)
□ 4 Ft. – COLUMN III (193.7 BV/DAY)
CONCENTRATION (ug/l)
0
20
40
60
80
100
120
140
TIME IN OPERATION (DAYS)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280

FIGURE 4

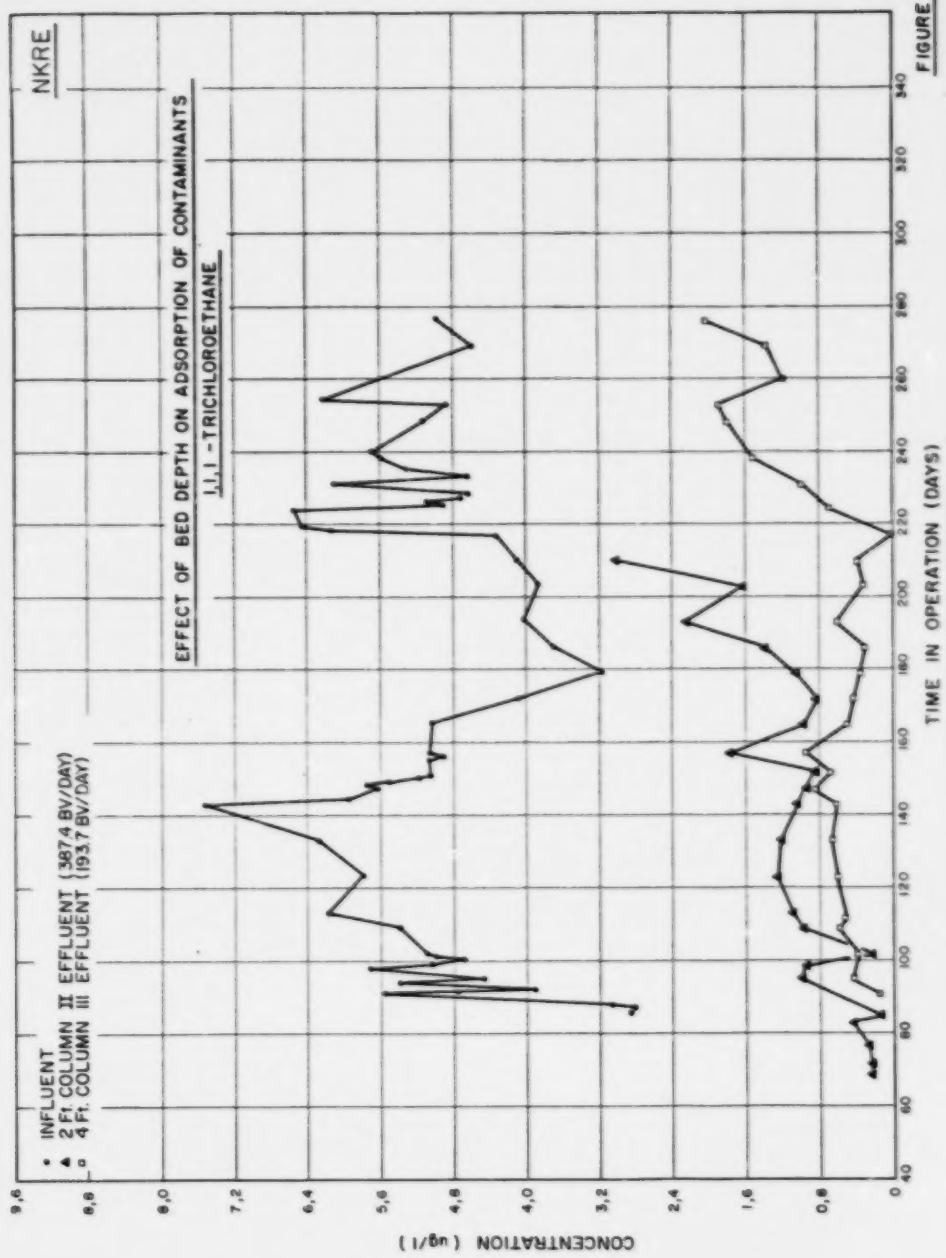

NKRE
EFFECT OF BED DEPTH ON ADSORPTION OF CONTAMINANTS
1,1,1 - TRICHLOROETHANE
• INFLUENT
▲ 2 Ft. COLUMN II EFFLUENT (387.4 BV/DAY)
○ 4 Ft. COLUMN III EFFLUENT (193.7 BV/DAY)
CONCENTRATION (ug/l)
TIME IN OPERATION (DAYS)

FIGURE 5

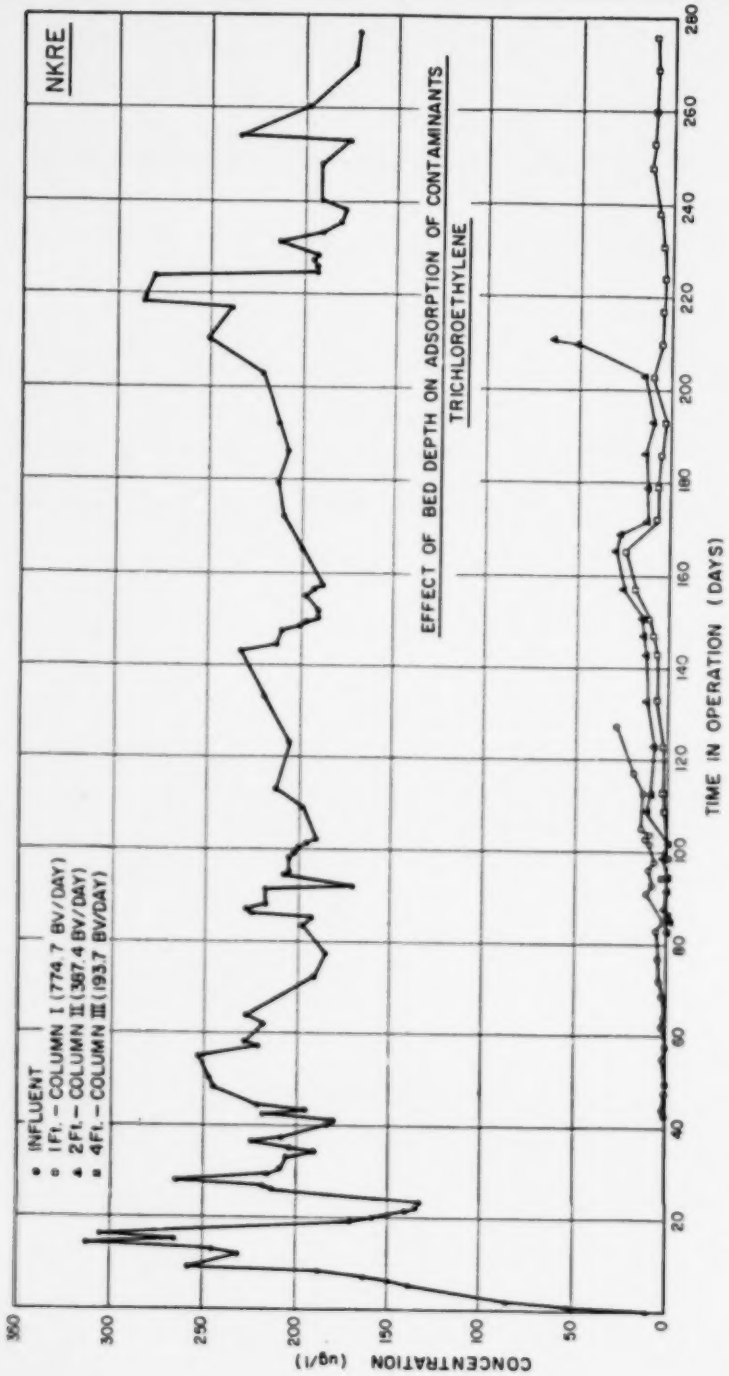

NKRE
EFFECT OF BED DEPTH ON ADSORPTION OF CONTAMINANTS
TRICHLOROETHYLENE
• INFLUENT
○ 1Ft. – COLUMN I (774.7 BV/DAY)
▲ 2Ft. – COLUMN II (387.4 BV/DAY)
■ 4Ft. – COLUMN III (193.7 BV/DAY)
CONCENTRATION (µg/l)
TIME IN OPERATION (DAYS)
0
50
100
150
200
250
300
350
20
40
60
80
100
120
140
160
180
200
220
240
260
280

FIGURE 6

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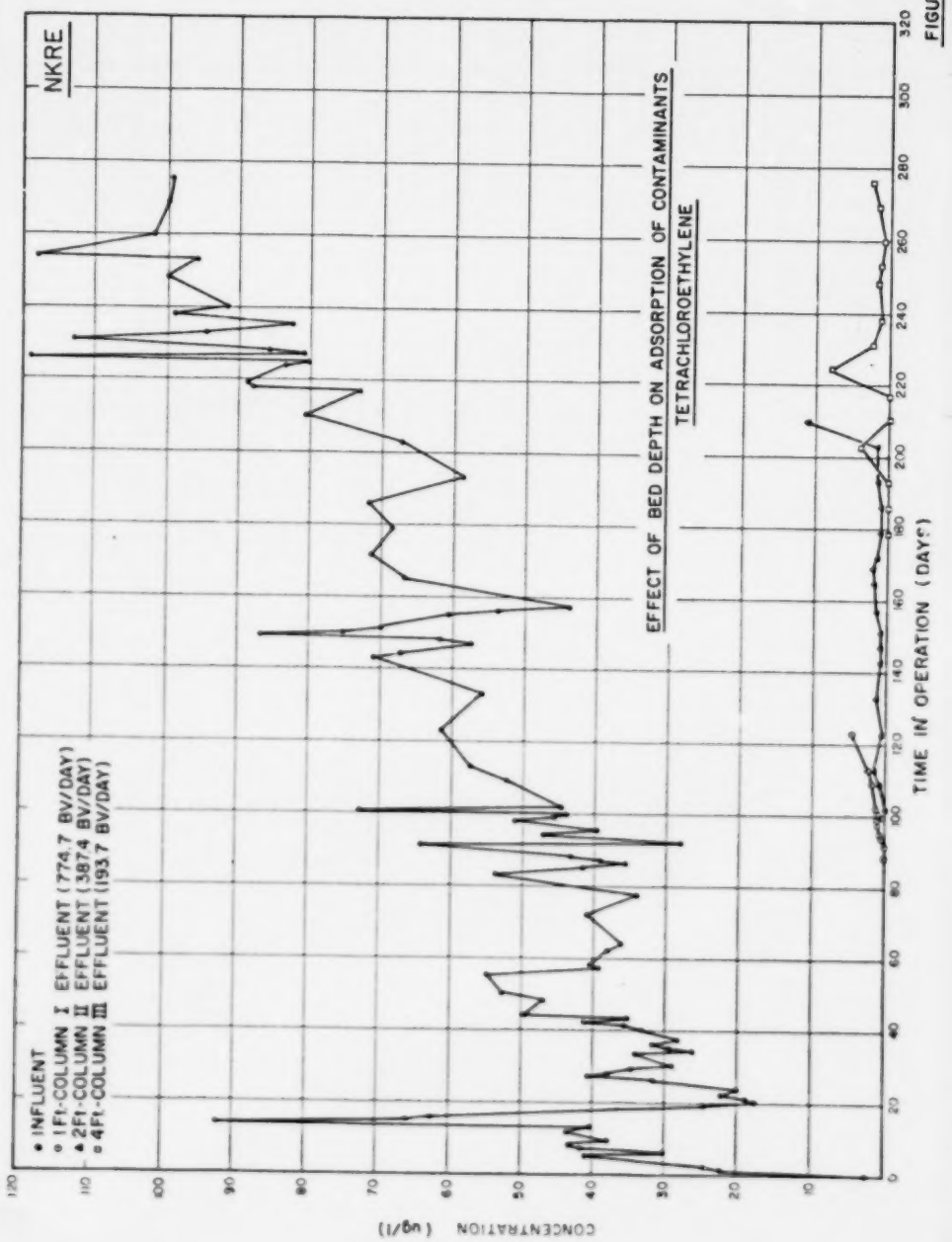

NKRE
EFFECT OF BED DEPTH ON ADSORPTION OF CONTAMINANTS
TETRACHLOROETHYLENE
• INFLUENT
○ 1Ft-COLUMN I EFFLUENT (774.7 BV/DAY)
▲ 2Ft-COLUMN II EFFLUENT (387.4 BV/DAY)
▫ 4Ft-COLUMN III EFFLUENT (193.7 BV/DAY)
CONCENTRATION (µg/l)
TIME IN OPERATION (DAYS)

FIGURE 7

It should be noted that for the influent, the concentration of the main contaminant, trichloroethylene, remained fairly constant after the first 25 days. Tetrachloroethylene increased erratically, yet steadily. Cis-1,2-dichloroethylene seemed to be increasing in the last 75 days of operation, although before that no trend was evident.

Column IV was brought on line for the purpose of comparing the performance of a virgin resin to that of the regenerated resin in Column I, both with 1 ft (0.30 m) bed depth. The first attempted regeneration of Column I was unsuccessful, possibly due to the condensation of the steam before it reached the resin. Breakthrough trends for the three major contaminants were compared for both columns and the results appear in Figures 8-10.

In general, the effluent contaminant level plots for Columns I and IV are similar, being practically parallel for tri- and tetrachloroethylene. The curves for cis-1,2-dichloroethylene, where breakthrough occurred much faster, indicate that the effluent concentrations eventually exceeded the influent concentrations, in both cases. Thereafter, each column's influent and effluent concentrations were similar. It is possible to construct a chart showing the length of time necessary for a compound to reach a specified effluent concentration from the breakthrough curves of the various columns. Figure 11 shows the plot of 4 selected effluent target levels (5, 10, 25 and 50 ug/l) versus resin bed depth for all contaminants except 1,1,1-trichloroethane, whose influent concentration did not exceed 5 ug/l. These results are generally inconclusive, except for the 25 ug/l cis-1,2-dichloroethylene target level which plots proportionately to depth.

The information from Figure 11 is presented in Figure 12 to show the relative efficiency of Ambersorb XE-340 in removing the three major contaminants. The resin was most effective in removing tetrachloroethylene. Even after more than 275 days of operation, the four-foot (1.22 m) resin bed still kept this contaminant below 5 ug/l. The resin was slightly better at adsorbing trichloroethylene than cis-1,2-dichloroethylene.

DIFFUSED AERATION STUDIES

Unlike resin adsorption, where the build-up of contaminants on the resin affects future performance, the aeration experiments were independent of time. Figures 13 through 16 compare the influent concentrations with the aeration effluent concentrations of the four compounds under consideration for several air:water ratios (volume to volume).

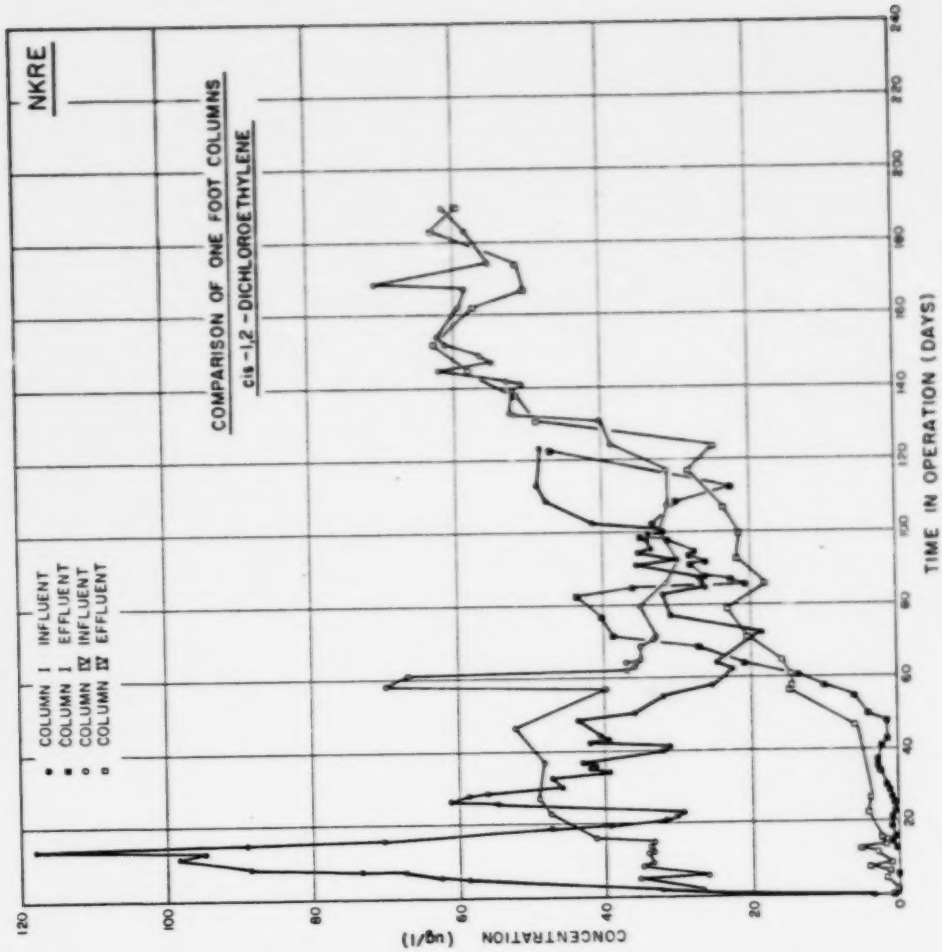

NKRE
COMPARISON OF ONE FOOT COLUMNS
cis -1,2 - DICHLOROETHYLENE
• COLUMN I INFLUENT
▪ COLUMN I EFFLUENT
○ COLUMN II INFLUENT
□ COLUMN II EFFLUENT
CONCENTRATION (ug/l)
TIME IN OPERATION (DAYS)

FIGURE 8

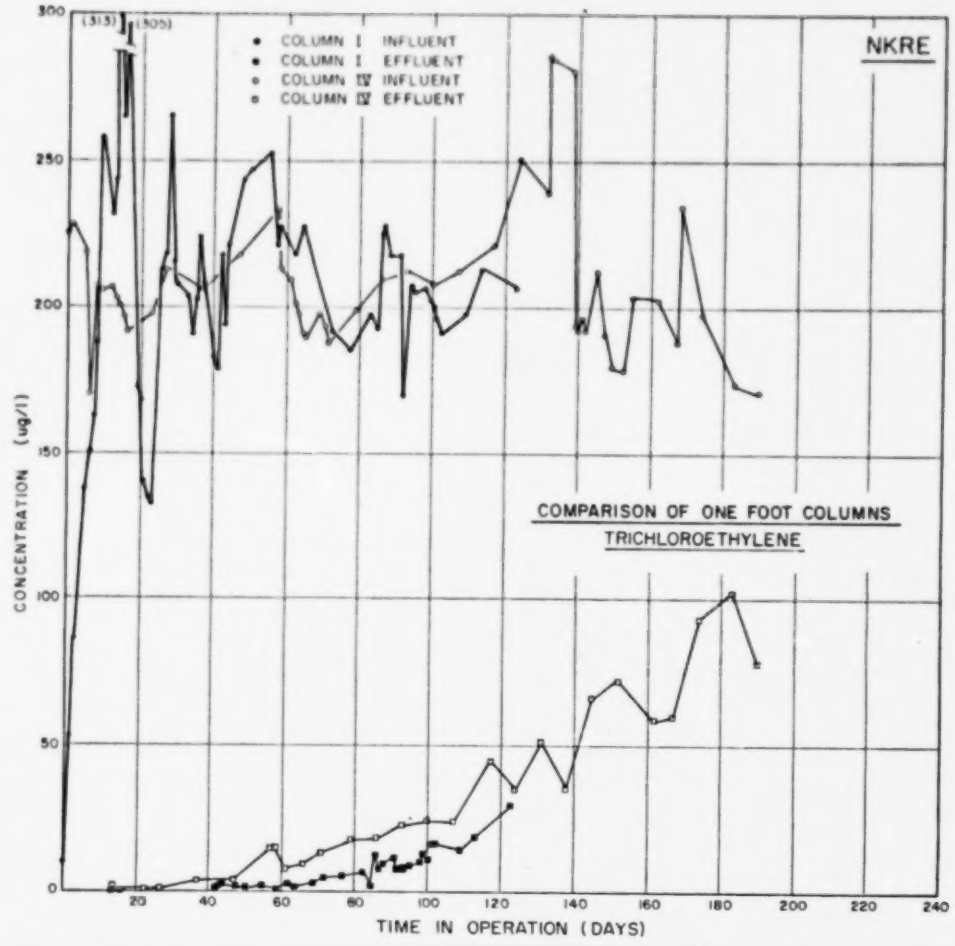

NKRE
COLUMN I INFLUENT
COLUMN I EFFLUENT
COLUMN IV INFLUENT
COLUMN IV EFFLUENT
(315)
(305)
COMPARISON OF ONE FOOT COLUMNS
TRICHLOROETHYLENE
CONCENTRATION (ug/l)
TIME IN OPERATION (DAYS)
0
50
100
150
200
250
300
20
40
60
80
100
120
140
160
180
200
220
240

FIGURE 9

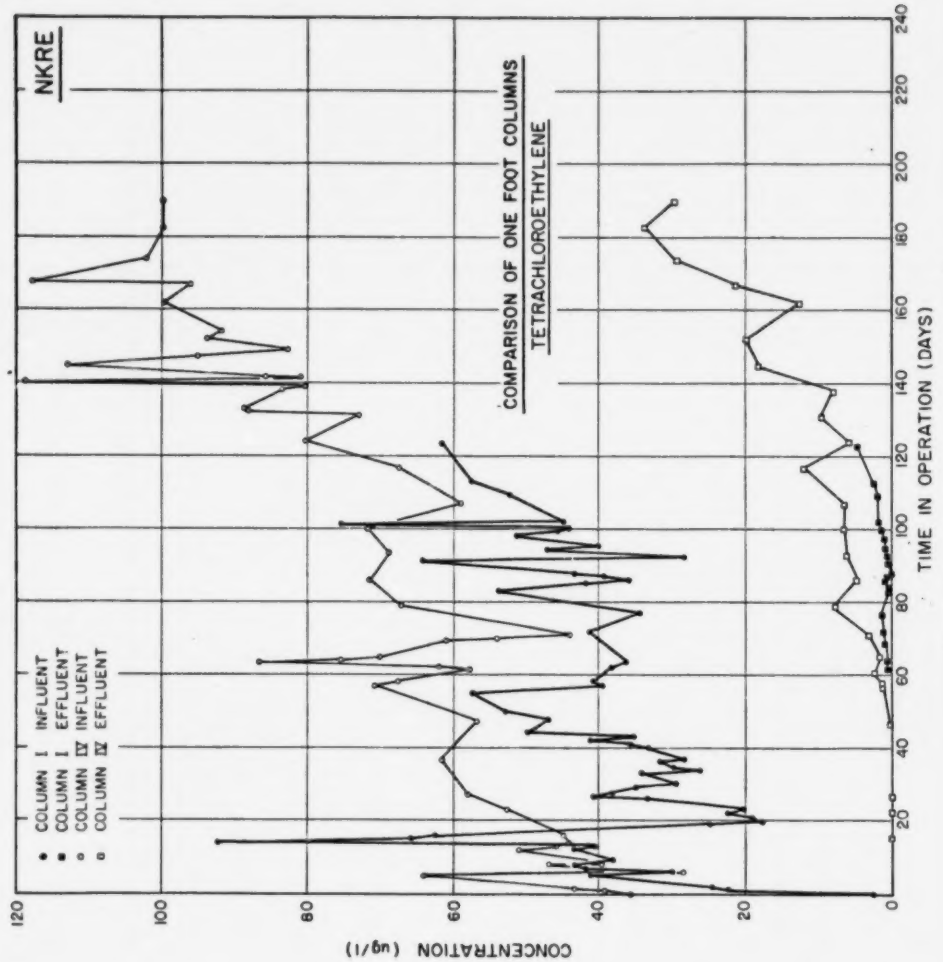
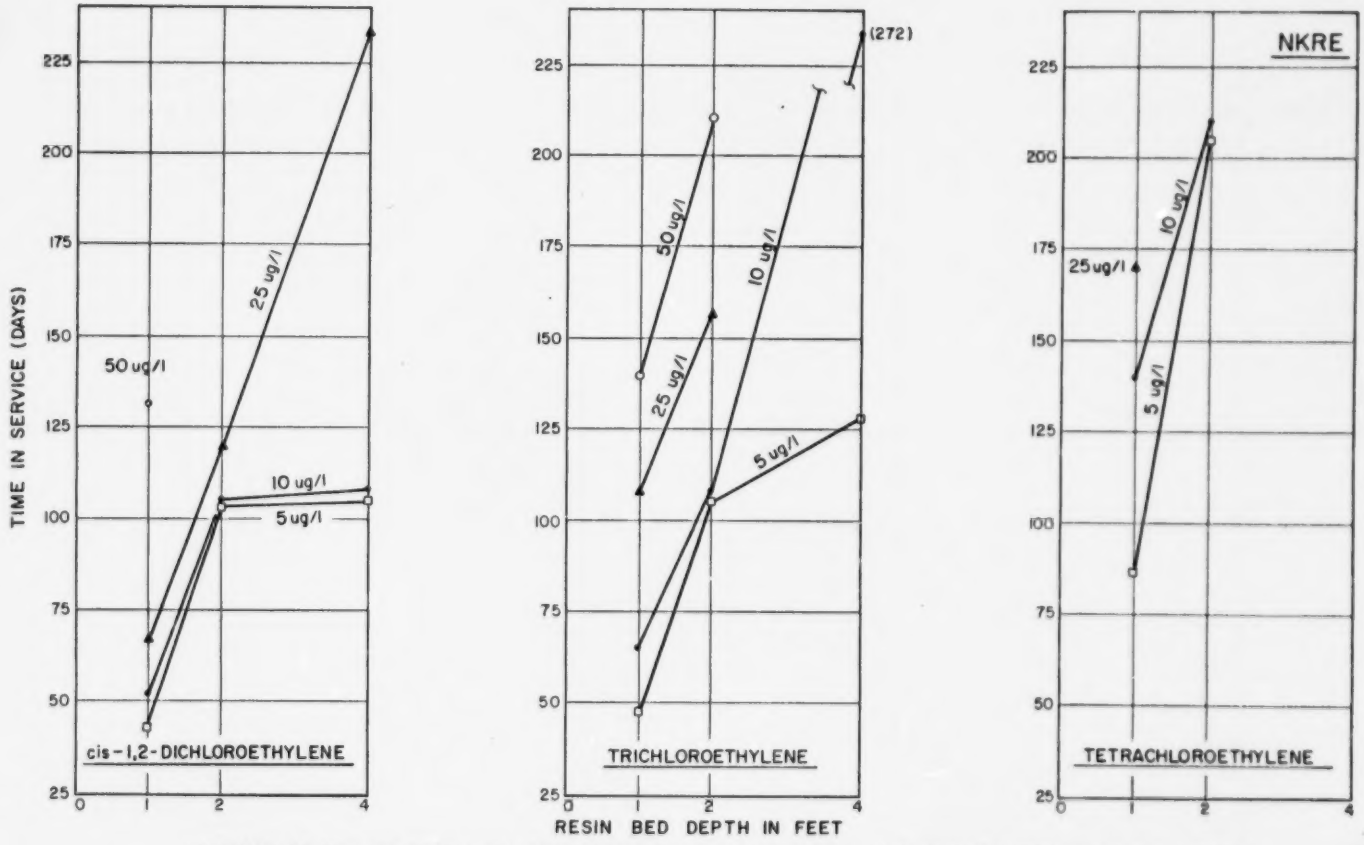
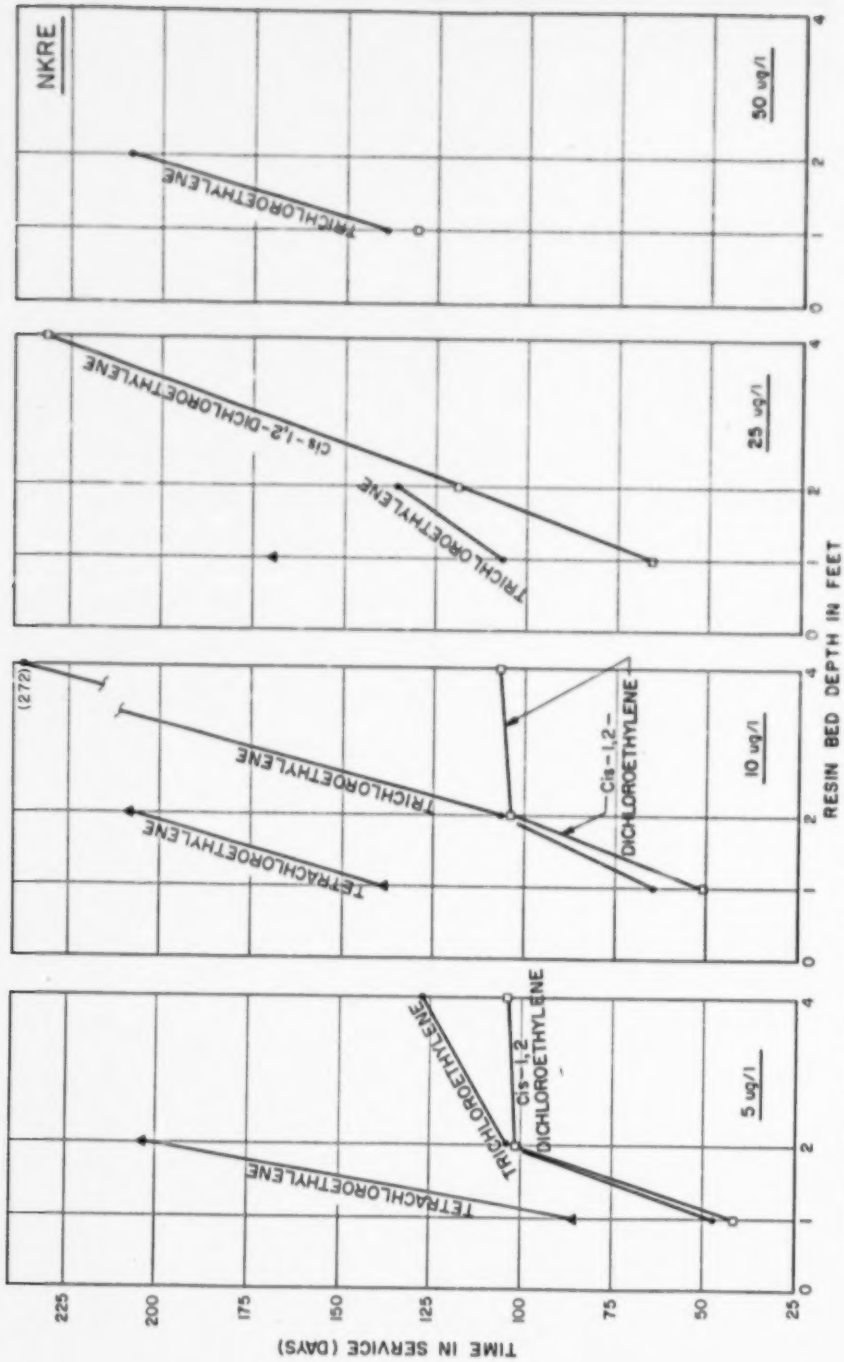

NKRE
COMPARISON OF ONE FOOT COLUMNS
TETRACHLOROETHYLENE
COLUMN I INFLUENT
COLUMN I EFFLUENT
COLUMN IV INFLUENT
COLUMN IV EFFLUENT
CONCENTRATION (ug/l)
TIME IN OPERATION (DAYS)
0
20
40
60
80
100
120
140
160
180
200
220
240

FIGURE 10



VARIANCE OF SERVICE TIME WITH BED DEPTH TO REACH SPECIFIED CONTAMINANT BREAKTHROUGH LEVELS

FIGURE 11



VARIANCE WITH BED DEPTH OF SERVICE TIME REQUIRED TO ACHIEVE BREAKTHROUGH LEVELS OF THE CONTAMINANTS

FIGURE 12

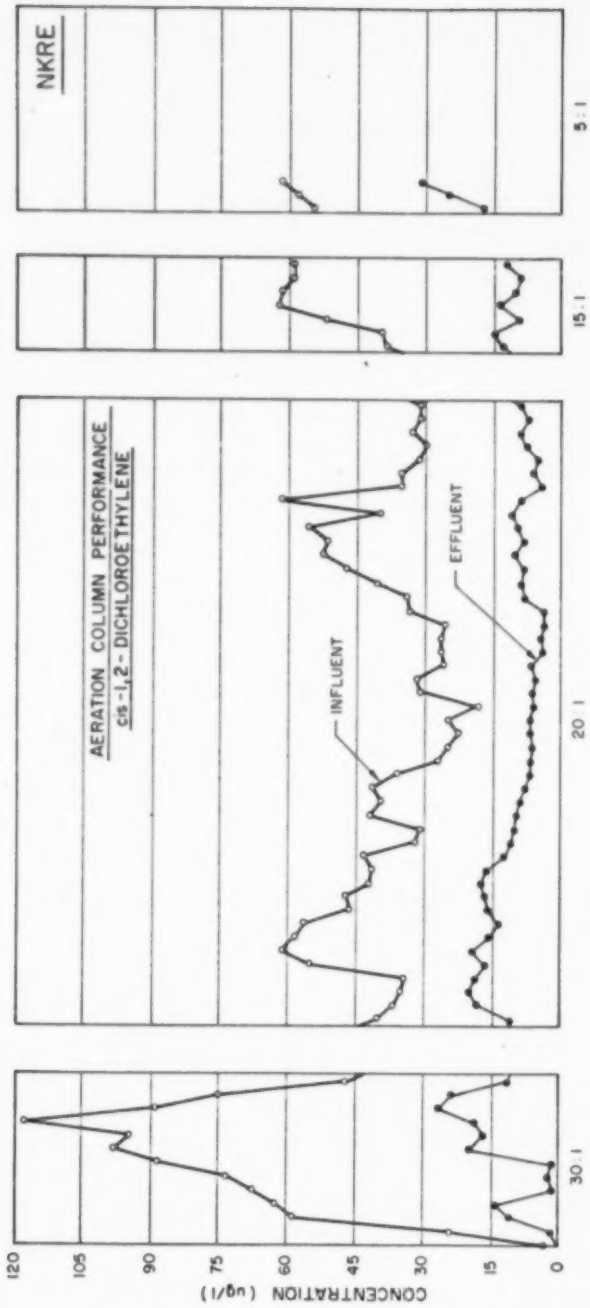

NKRE
AERATION COLUMN PERFORMANCE
cis-1,2-DICHLOROETHYLENE
INFLUENT
EFFLUENT
CONCENTRATION (ug/l)
120
105
90
75
60
45
30
15
0
30:1
20:1
15:1
5:1
AIR : WATER RATIO

FIGURE 13

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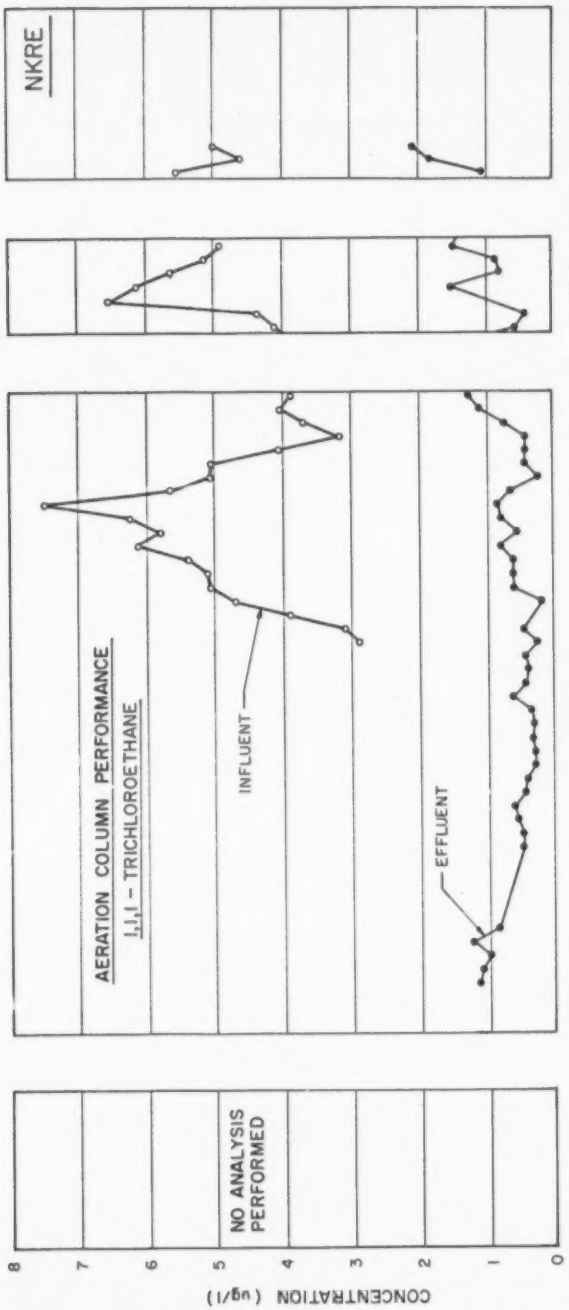

FIGURE 14

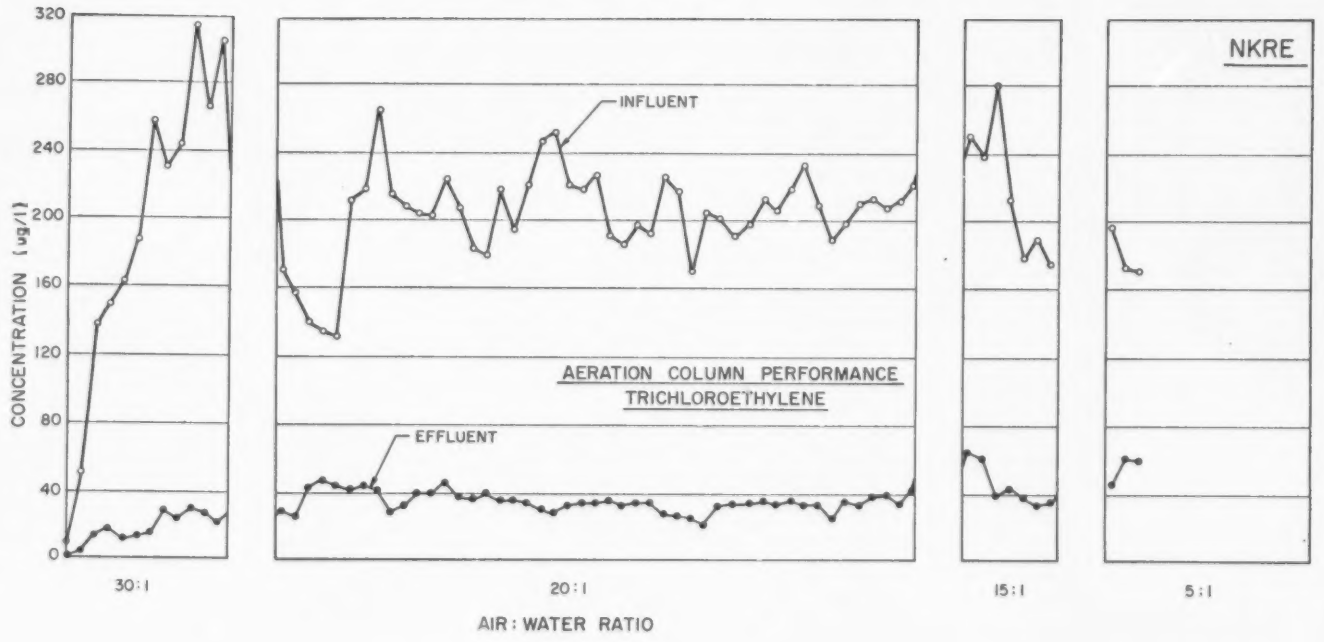
320
280
240
200
160
120
80
40
0
CONCENTRATION (ug/l)
INFLUENT
EFFLUENT
AERATION COLUMN PERFORMANCE
TRICHLOROETHYLENE
NKRE
30:1
20:1
15:1
5:1
AIR: WATER RATIO

FIGURE 15

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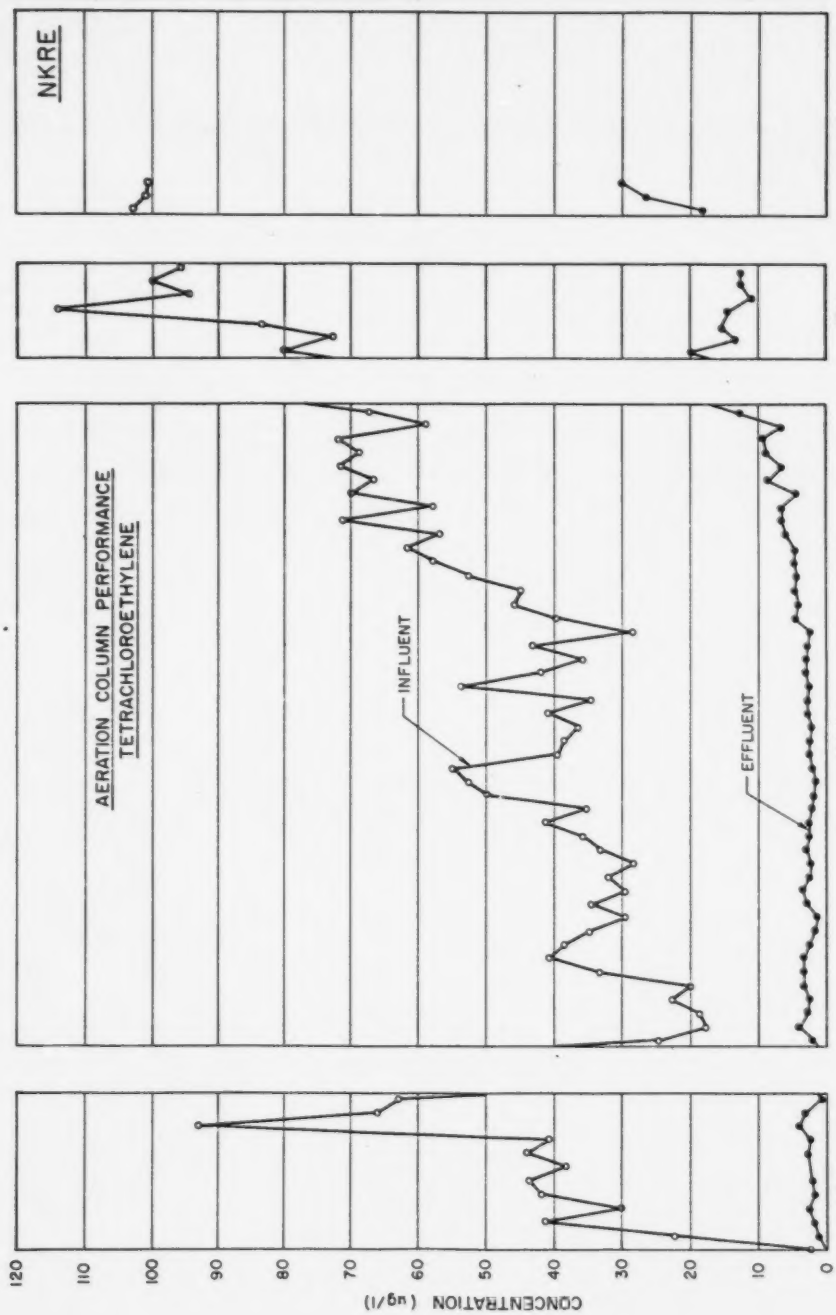

FIGURE 16.

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Aeration testing began at an air to water ratio of 30:1 and continued for 20 days. On the 21st day a ratio of 20:1 was initiated and maintained for 188 days. A week later the 15:1 ratio was utilized for the following 44 days. The final ratio of 5:1 was used for the last 16 days.

From the graphs, it is apparent that the removal of tetrachloroethylene is more efficient than that of cis-1,2-dichloroethylene. Solubilities for cis-1,2-dichloroethylene, trichloroethylene, tetrachloroethylene, and 1,1,1-trichloroethane are 3,500 mg/l, 1,100 mg/l, 140 mg/l, and 720 mg/l, respectively. This indicates that limited solubility is a more important factor than volatility, at least under the conditions used in these experiments.

Temperature may also play a major role in contaminant removal efficiency. It is particularly noticeable on cis-1,2-dichloroethylene that the effluent concentration is lowest towards the middle of the 20:1 testing, corresponding to the middle of summer when the temperatures were warmest.

Figure 17 shows the average values for the effluent concentrations of the four contaminants at the different aeration ratio used. It can be seen that aeration alone at air:water ratios of at least 15:1 will meet the current New York State guidelines of 50 ug/l per contaminant. At 5:1, trichloroethylene exceeds the recommended maximum of 50 ug/l and the total level of all contaminants under consideration exceeds 100 ug/l.

Results of analyses presented in Appendix C illustrate that the aeration system had no appreciable impact on contamination of the air in the vicinity of the aeration column. Therefore, this system does not create a waste disposal problem.

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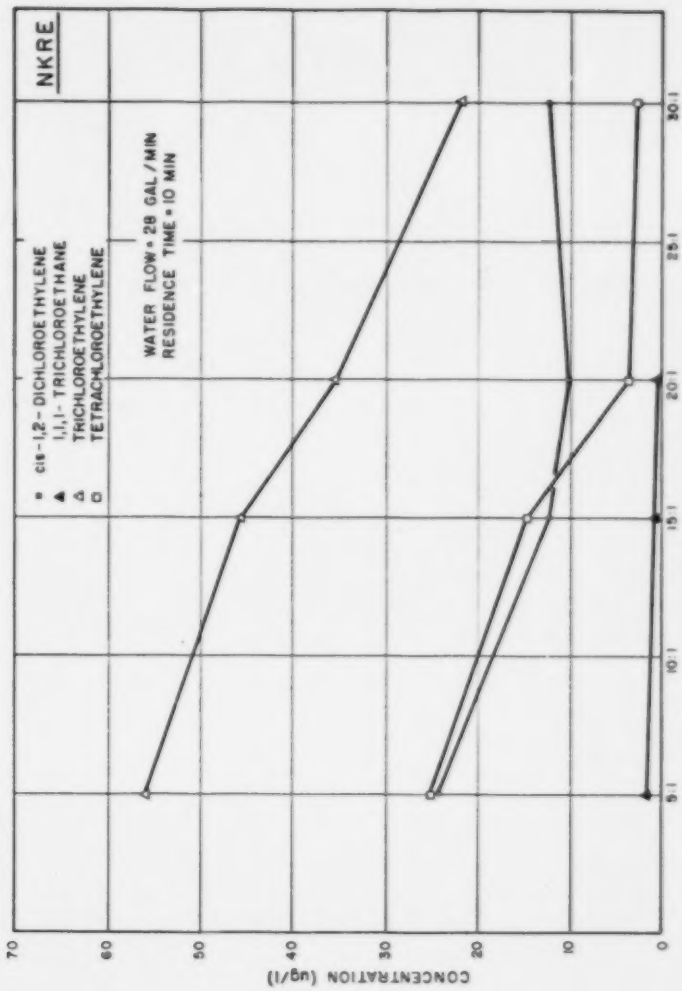
FIGURE 17



AVERAGE AERATION EFFLUENT LEVELS AT SELECTED AIR : WATER RATIOS

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SECTION 7

REGENERATION

In many ways the regeneration feasibility was the most important part of the resin performance testing, because only if the resin could be regenerated quickly, easily and inexpensively would it be economical in treating waters containing these organic contaminants.

The first attempt to regenerate a resin bed with steam took place on June 21 when the effluent concentration of cis-1,2-dichloroethylene from Column I was greater than the influent concentration, possibly because of cis-1,2-dichloroethylene being displaced from sites on the resin. However, the other major contaminants still were being removed effectively: the effluent concentration of tetrachloroethylene was less than 1.5 ug/l and trichloroethylene was slightly greater than 5 ug/l.

The regeneration procedure followed was that prescribed by the Rohm and Haas Co., manufacturer of Ambersorb XE-340. The column was first backwashed for 30 minutes, and then was completely drained. The column and piping were wrapped in thermal insulation and the 11 lb/hr (5 kg/hr) steam generator activated. Steam entered the top of the column and flowed down in the same direction as the well water, exiting at the bottom. Regeneration was considered underway when steam was seen exiting the column. After two hours of steaming, the resin bed was allowed to cool. Tap water was then introduced slowly through the bottom of the column, rehydrating the resin. The resin was then backwashed for 30 minutes. It should be noted that only 3 bed volumes of steam were employed.

Analysis of condensate samples could not be performed at the site at that time because the concentrator was not functioning properly. It was expected, however, that this procedure would produce a resin bed which would have about 90% of the lifetime of the virgin resin (1). Samples of the condensate were taken to MERL, Cincinnati, for analysis. Results of this analysis showed no significant reduction in contaminant levels in the resin over the period during which regeneration was presumed to have occurred.

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To evaluate the effect of regeneration, the percentage remaining for each of the three major contaminants was computed and is presented graphically on Figures 18 through 20 for each regeneration of Column I. The first regeneration attempt of Column I occurred after the sampling on Day 85 and was not successful. There was a decrease in the concentration of cis-1,2-dichloroethylene after this process. However, the trichloroethylene's effluent concentration increased, and the concentration increased, and the concentration of tetrachloroethylene did not seem to have been affected by the process.

The next attempt to regenerate Column I took place in mid-August. Rohm and Haas believed the failure to regenerate the resin was due to condensation of the steam before reaching the resin. To counteract this, all tubing conveying the steam to the columns was insulated and heated and a large volume of steam was also deemed necessary. For this purpose. Rohm and Haas shipped a 20 lb/hr (9.07 kg/hr) steam generator to the site for use in this and future regenerations. The analytical system was functioning properly and was used to monitor the concentration of contaminants in the steam condensate collected. Steam flow again was concurrent to operating flow.

Because the condensate was being analyzed as the regeneration was progressing, it soon became evident that a longer period than expected would be needed for adequate regeneration. The column was steamed for more than eighteen hours, and the contaminants were still present in appreciable quantities in the condensate. Figure 21 traces the contaminants' concentrations in the condensate as a function of time. Smooth curves should not be expected because the steam flow was not constant due to considerable trouble caused by electrical problems in the steam generator circuit. The large increase in contaminants shown in Figure 21 resulted from the column cooling overnight. When the steam was introduced the next morning a slug of contaminants was removed.

No attempt was made to continue the regeneration to the zero contaminant level in condensate. This would have been an extremely lengthy and uneconomical task. However, since the condensate was being continually monitored, the quantity of contaminants removed from the resin could be estimated. Assuming that the average contaminant load in the well water was 300 ug/l, an estimate of the amount of contaminant on the column could be made. From these two figures an idea of the percent regeneration could be obtained.

Figure 21 shows that cis-1,2-dichloroethylene was the first of the major pollutants to have been cleaned from the resin. Later, trichloroethylene decreased in concentration, showing

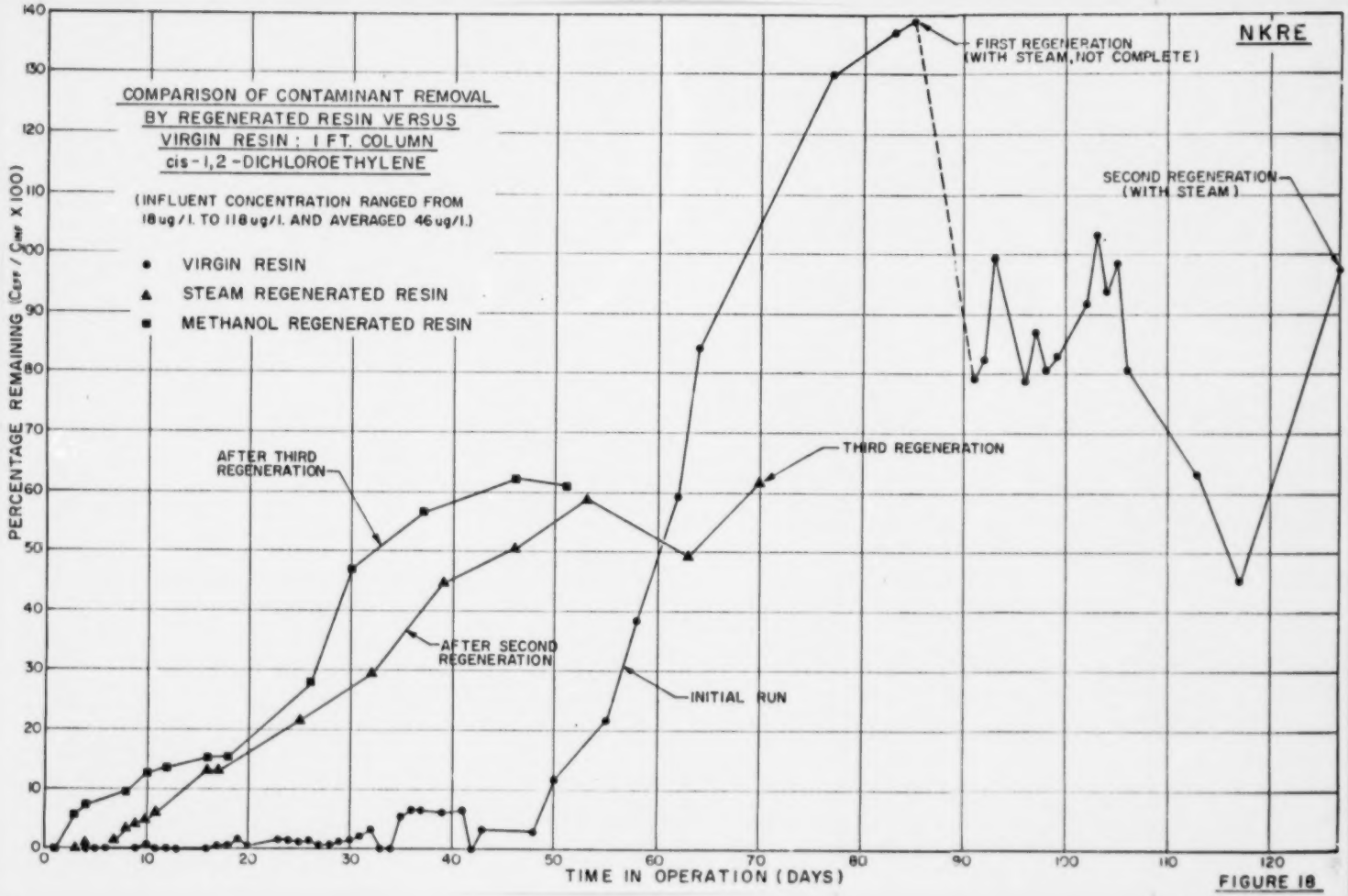
COMPARISON OF CONTAMINANT REMOVAL
BY REGENERATED RESIN VERSUS
VIRGIN RESIN ; 1 FT. COLUMN
cis-1,2-DICHLOROETHYLENE
(INFLUENT CONCENTRATION RANGED FROM
18 ug/l. TO 118 ug/l. AND AVERAGED 46 ug/l.)
VIRGIN RESIN
STEAM REGENERATED RESIN
METHANOL REGENERATED RESIN
NKRE
FIRST REGENERATION
(WITH STEAM, NOT COMPLETE)
SECOND REGENERATION
(WITH STEAM)
THIRD REGENERATION
AFTER THIRD
REGENERATION
AFTER SECOND
REGENERATION
INITIAL RUN
PERCENTAGE REMAINING (Cef / Cinf X 100)
TIME IN OPERATION (DAYS)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140

FIGURE 18

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NKRE

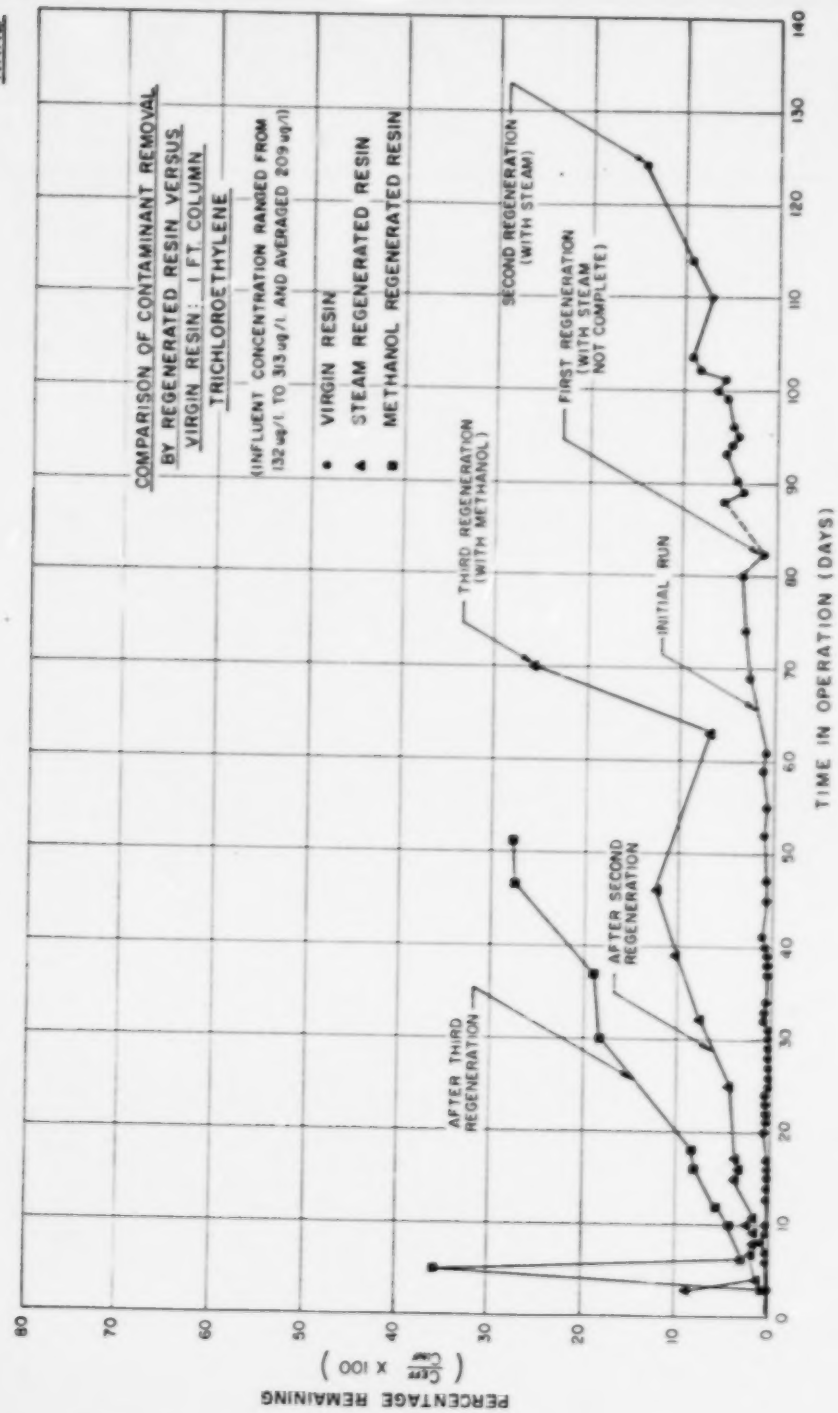

FIGURE 19

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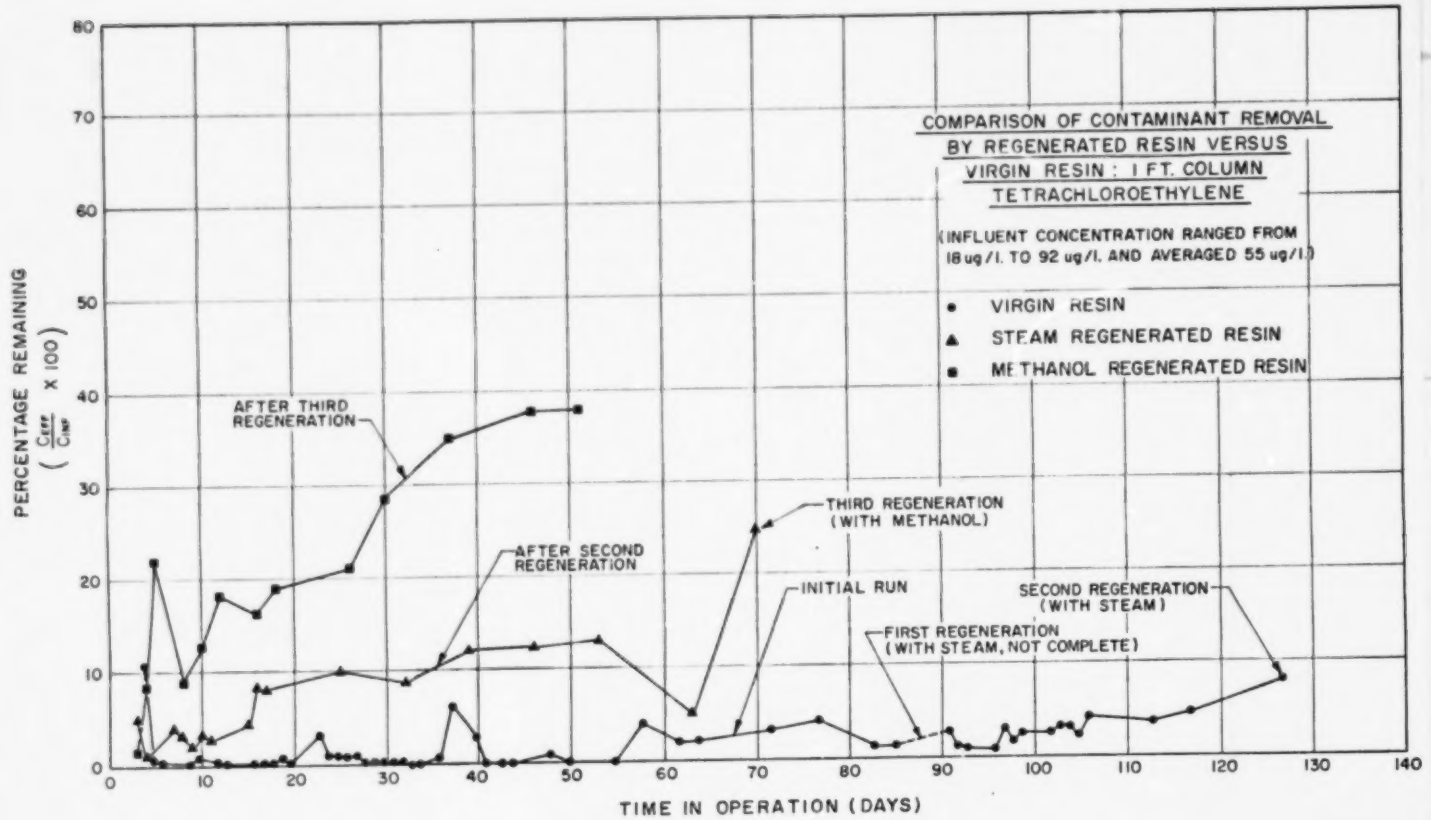

FIGURE 20

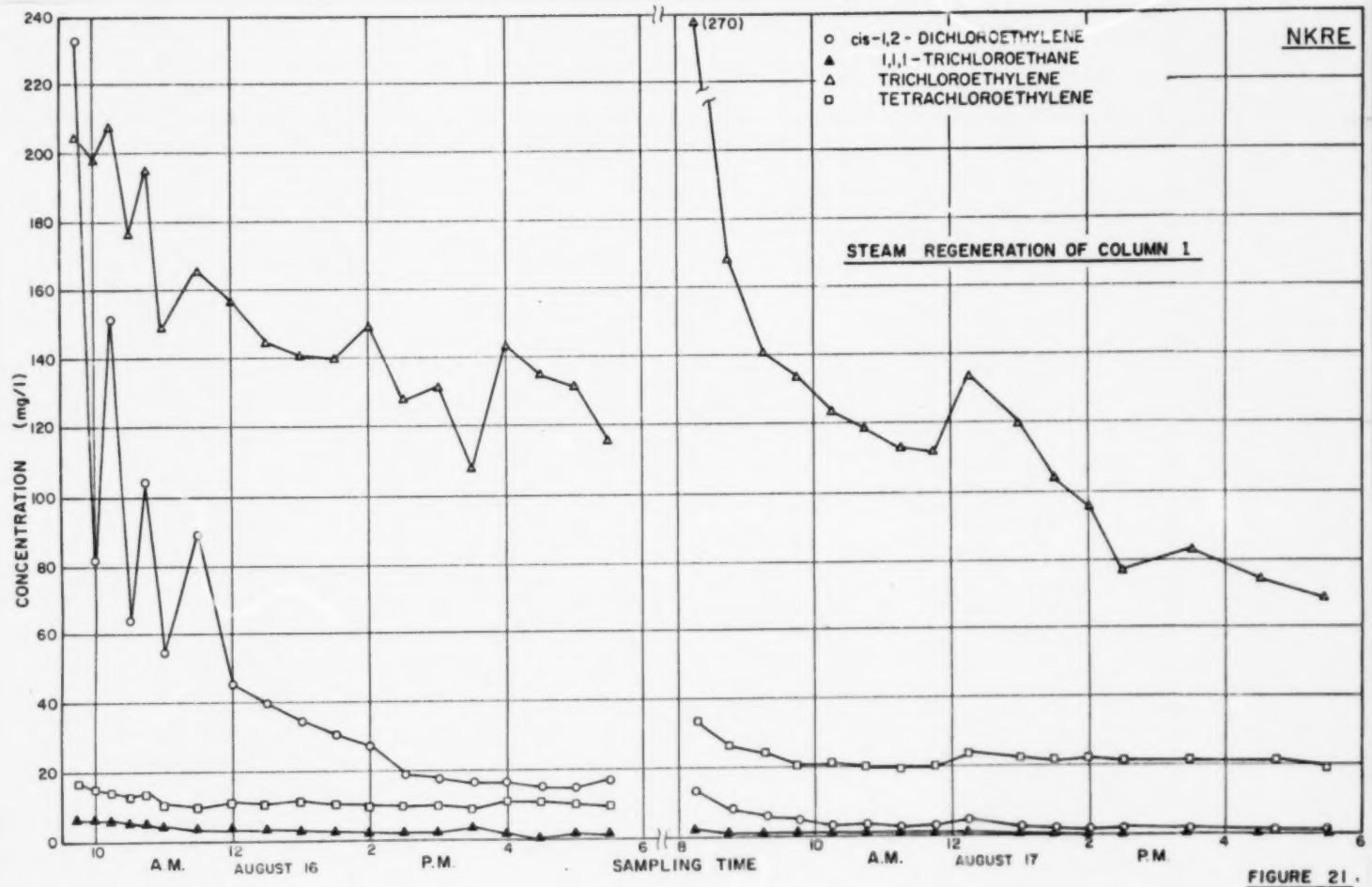
NKRE
cis-1,2 - DICHLOROETHYLENE
1,1,1 - TRICHLOROETHANE
TRICHLOROETHYLENE
TETRACHLOROETHYLENE
STEAM REGENERATION OF COLUMN 1
CONCENTRATION (mg/l)
240
220
200
180
160
140
120
100
80
60
40
20
0
(270)
10
12
2
4
6
8
A.M.
AUGUST 16
P.M.
SAMPLING TIME
A.M.
AUGUST 17
P.M.

FIGURE 21.

that it too was being driven from the resin. Tetrachloroethylene showed no appreciable change in concentration throughout the procedure.

The steam, aside from heating the resin, should cause the contaminants on the resin to boil, then dissolve in the vapors, and thus be carried away from the resin. This worked well with cis-1,2-dichloroethylene, but not with tetrachloroethylene since tetrachloroethylene boils at 112°C and the steam used was at a temperature of 100°C which could not boil the compound. However, liquid steam (water) and tetrachloroethylene form a binary azeotrope, a solution whose composition is not altered by vaporization and thus has a constant boiling point. The azeotrope, which is 82.8% tetrachloroethylene, boils at 88.5°C. If the azeotrope is formed, the steam should be able to remove it. The condensate curve, Figure 21, appears quite flat, indicating that an azeotrope was not formed.

As the steam passed over the resin in the same direction as the water flow, the contaminants near the top of the resin bed were forced the full length of the bed encountering vacant sites in the resin onto which they were adsorbed. As seen in Figure 12, cis-1,2-dichloroethylene was the least tightly held of the contaminants, and thus came through first.

If the steam's direction of flow were opposite to that of the water, the stripped contaminants would pass through fully occupied resin sites, and the regeneration would theoretically proceed much more quickly and efficiently. The performance of the resin was significantly improved by regeneration, but it was not as effective as that of the virgin resin.

By the end of October, both Columns I and II were again ready for regeneration. It was decided to regenerate Column II first, using a downward flow of steam, and then Column I, using an upward flow of steam, counter to that of the water stream. For these regenerations, the 11 lb/hr (4.99 kg/hr) and the 20 lb/hr (9.07 kg/hr) steam generators were used in parallel.

When steam was applied to the bottom of Column I, water, which condensed in the column, accumulated above the resin bed. Because the steam came in through the only opening at the bottom of the column, there was no way for the water to escape and a reflux condition within the column developed. The effort was aborted and a methanol regeneration was conducted to solubilize the contaminants. The whole process was completed in a day and total contaminant levels as high as 3 g/l (3×10^6 ug/l) were found in the used methanol. Theoretically, in excess of 100% of the contaminants were removed. The results of this regeneration are shown in Figures 18 through 20. Although contaminant levels were reduced, breakthrough occurred much sooner than with virgin resins.

Regeneration of a one-foot (0.30 m) column required approximately 26 hours and approximately 60 bed volumes of steam using a downward flow of steam, while regeneration of the two-foot (0.61 m) column required approximately 38 hours and approximately 60 bed volumes of steam. When plotted, the contaminant levels in the condensate were similar to the curves in Figure 21. The total contaminant concentration for the final sample taken was under 50 mg/l, the limit which had been set before starting. After that regeneration, Column II was on line for 58 days. During that time, cis-1,2-dichloroethylene began leaking, as shown in Figure 22. There was no appreciable leakage for the other compounds, although trichloroethylene was holding at about 4 ug/l. In this case, the regeneration was considered a partial success.

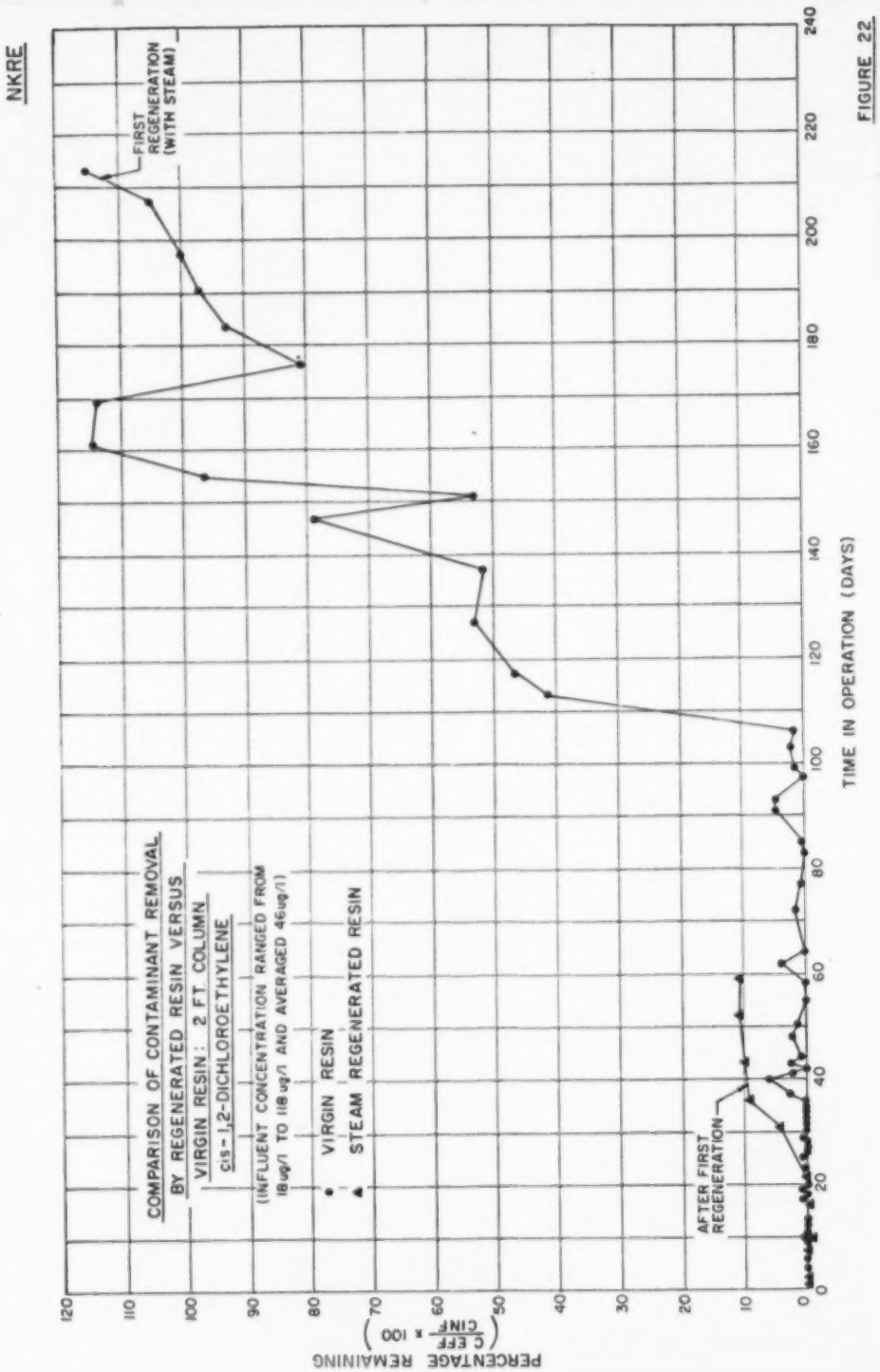
NKRE
COMPARISON OF CONTAMINANT REMOVAL BY REGENERATED RESIN VERSUS VIRGIN RESIN: 2 FT. COLUMN
cis-1,2-DICHLOROETHYLENE
(INFLUENT CONCENTRATION RANGED FROM 18ug/l TO 118 ug/l AND AVERAGED 46ug/l)
• VIRGIN RESIN
▲ STEAM REGENERATED RESIN
FIRST REGENERATION (WITH STEAM)
AFTER FIRST REGENERATION
PERCENTAGE REMAINING (C EFF / CINF x 100)
TIME IN OPERATION (DAYS)
0
10
20
30
40
50
60
70
80
90
100
110
120
0
20
40
60
80
100
120
140
160
180
200
220
240

FIGURE 22

SECTION 8

FULL-SCALE INSTALLATIONS

ADAPTABILITY OF SYSTEMS

A. Diffused Aeration System

The aeration system, presently being utilized at Glen Cove, can be designed and installed for a full-scale operation if the desired effluent quality for each contaminant is not less than those attainable at the air to water ratios presented in this report. In general, if the New York State guidelines are to be used, the aeration system tested in this phase can be successfully utilized in a full-scale treatment operation.

B. Resin System

The resin system achieves a much better quality effluent than the aeration system but requires more testing to determine necessary design parameters before it can be designed and installed on a full-scale basis. The major parameters which must be developed or determined before full-scale installation relate to an efficient regeneration method. Here, testing must verify and/or develop the amount of steam or solvent required to regenerate the resin, the adsorbent ability of the regenerated resins, and a treatment or disposal system for the condensate.

ESTIMATED COSTS FOR GLEN COVE, N.Y.

A. Diffused Aeration System

To obtain a range of costs for a full-scale installation, flows of 1, 2 and 5 mgd (3785-18,925 m^3/day) were utilized. Based on the results of the testing, an air to water ratio of 20:1, which will meet the New York State guidelines, was utilized along with a tank having a residence time of more than 10 minutes. Based on these parameters, the estimated capital costs for the flows indicated ranged from $198,000 to $633,000. The annual operating costs, including amortization,

maintenance, operations, and electricity at a local cost of $0.09 per kwh, range from $102,000 to $348,000 or between $0.19 and $0.28 per 1000 gallons (3,785 liters) treated. This cost is relatively high mainly due to the local cost of electricity. A summary of the cost estimate is presented in Table 1 and in Figures 23, 24 and 25.

B. Resin System

The estimated cost for the resin system is based on data and costs provided by the manufacturer, Rohm and Haas, at 1980 dollars. Again, using flows of 1, 2 and 5 mgd (3,785-18,925 m^3/day) for sizing purposes and based on an application flow rate of 4 gpm/ft^3 (0.42 lpm/m^3) of adsorbent, and considering two resin columns operating in series with an empty bed contact time of 2 minutes, the estimated capital costs range from $420,000 to $1,200,000. The resin system has an estimated annual operating cost including amortization, electricity (at $0.09 per kwh) steam for regeneration, maintenance, operation and other requirements ranging from $113,000 to $328,000, or between $0.18 and $0.31 per 1000 gallons (3785 liters) treated based on complete regeneration of the resin every 3 months. The regeneration of each column will be performed separately with the column not being regenerated, handling an application flow rate of 8 gpm/ft^3, thereby having an empty bed contact time of 1 minute during regeneration periods. A summary of these estimated costs is presented in Table 2 and in Figures 26, 27 and 28.

It should be noted that the estimated volume of steam or solvent required for regeneration is based on laboratory conditions, since the proper amounts could not be determined in the field during this phase. Also, the cost of disposing and/or handling of the waste regenerant is not included since no system for this has been demonstrated. These factors can influence the estimated costs.

TABLE 1

COST ESTIMATE - AERATION SYSTEM

(Based on 1980 Dollars)

		1 MGD (3785 m^3/d)	2 MGD (7570 m^3/d)	5 MGD (18925 m^3/d)
A.	Capital Cost			
1.	Aeration Storage Tank	$ 45,000	$ 66,000	$ 95,000
2.	Air Compressors	62,000	100,000	225,000
3.	Air Piping	37,000	62,000	150,000
4.	Control Building	32,000	50,000	100,000
5.	Electrical & Instrumentation	12,000	19,000	38,000
6.	Miscellaneous (Excavation, backfill, etc.)	10,000	14,000	25,000
		$198,000	$311,000	$633,000
B.	Annual Operating Cost			
1.	Electricity: $0.03/kwh	15,000	39,000	75,000
	0.06/kwh	30,000	60,000	147,600
	0.09/kwh	44,000	90,000	222,000
	0.12/kwh	60,000	120,000	296,000
2.	Maintenance 3% of Equipment Cost	3,500	5,400	12,400
3.	Operators	20,000	20,000	20,000
4.	Quality Control	9,000	9,000	9,000
5.	Amortization			
	Construction (8% for 10 yrs. - CFRO, 10185)	8,700	13,200	22,400
	Mechanical (8% for 10 yrs. - CFRO. 14903)	16,800	27,000	61,600
	Total Estimated Annual Cost			
	$0.03/kwh	$73,000	$ 104,600	$200,400
	0.06/kwh	88,000	134,698	273,000
	0.09/kwh	102,000	164,600	347,400
	0.12/kwh	118,000	199,600	421,400
	Cost per 1000 gal. Treated			
	$0.03/kwh	$0.173	$0.143	$0.110
	0.06/kwh	0.227	0.184	0.150
	0.09/kwh	0.279	0.225	0.190
	0.12/kwh	0.323	0.266	0.231

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NKRE

AERATION SYSTEM
CAPITAL COST

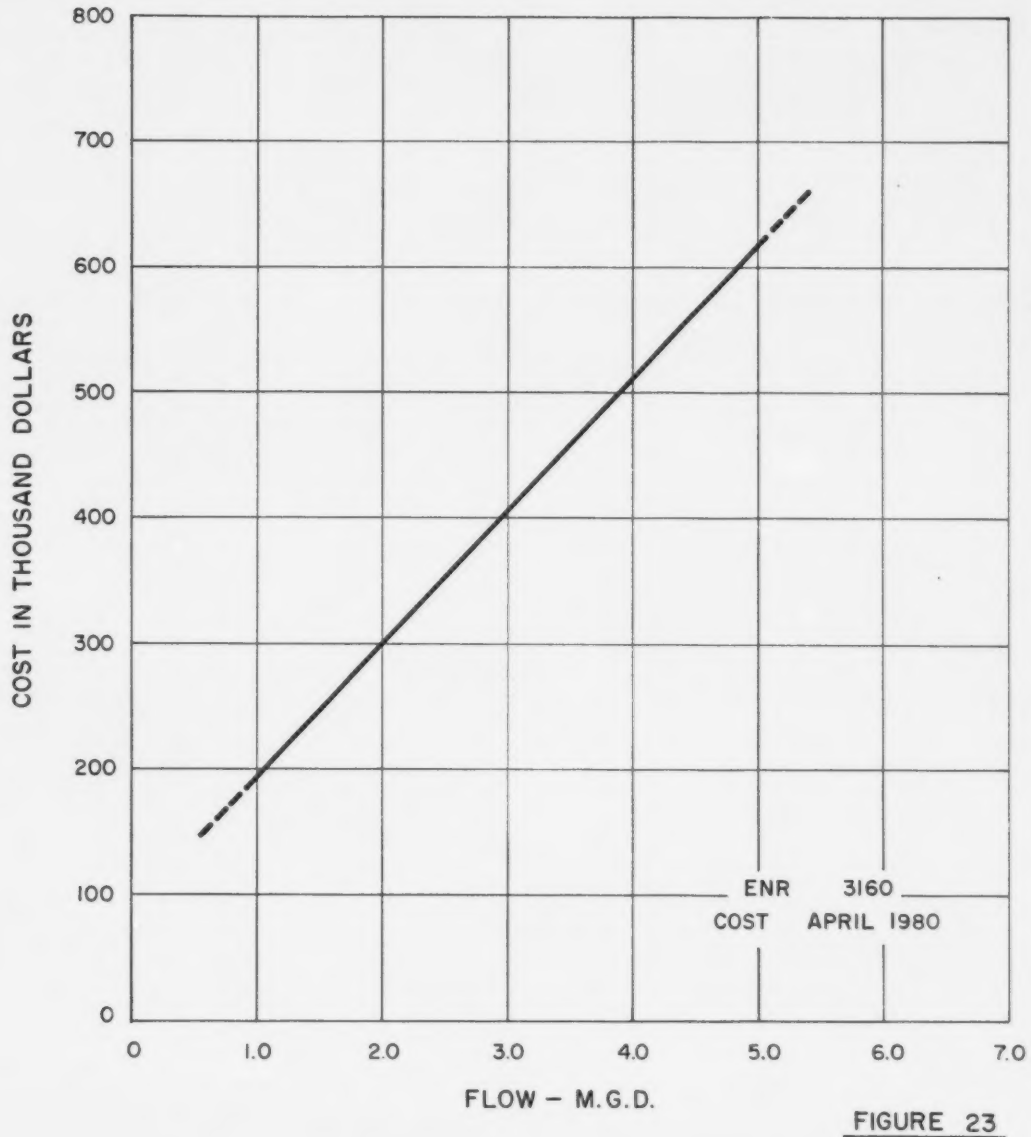

FIGURE 23

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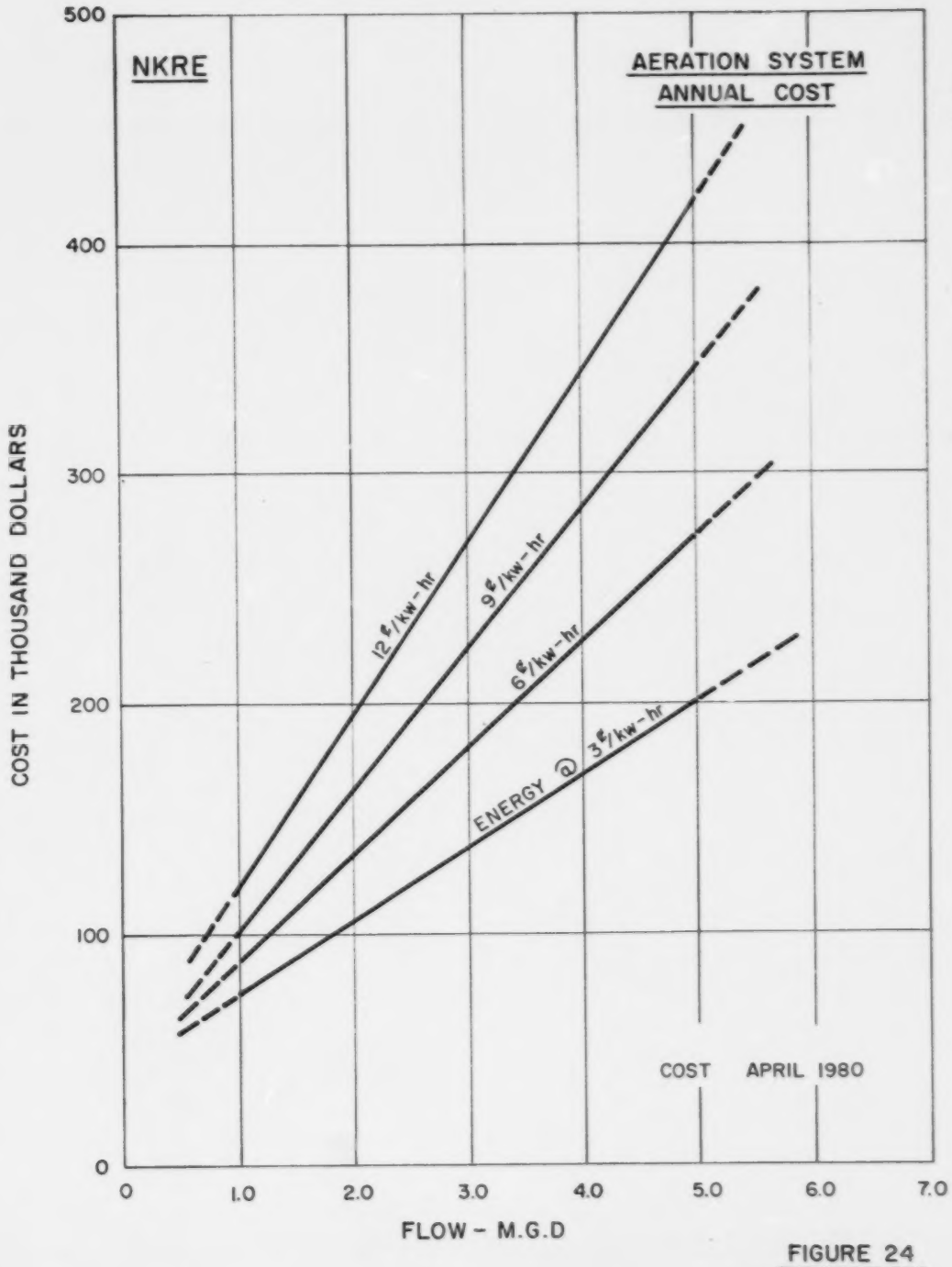
NKRE
AERATION SYSTEM
ANNUAL COST
500
400
300
200
100
0
COST IN THOUSAND DOLLARS
12¢/kw-hr
9¢/kw-hr
6¢/kw-hr
ENERGY @ 3¢/kw-hr
COST APRIL 1980
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
FLOW - M.G.D

FIGURE 24

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NKRE

AERATION SYSTEM
ANNUAL COST
PER THOUSAND
GALLONS TREATED

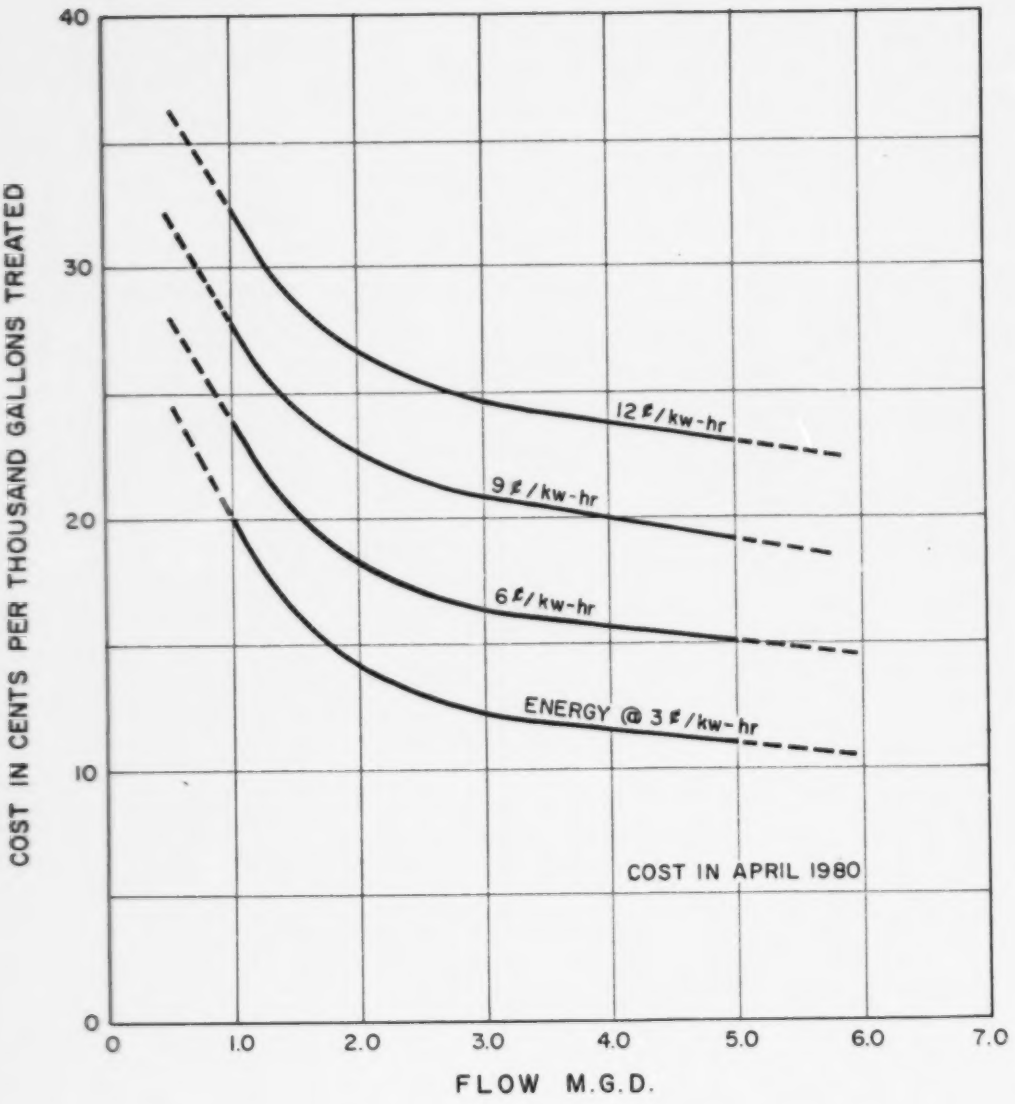

FIGURE 25

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TABLE 2

COST ESTIMATE - RESIN SYSTEM

(Based on 1980 Dollars and data provided by Rohm and Haas)

	1 MGD (3785 m^3/d)	2 MGD (7570 m^3/d)	5 MGD (18925 m^3/d)
A. Capital Cost			
1. Installed equipment cost including: Resin containers, Steam generator, Piping and valves, Electrical requirements	$ 375,000	$ 565,000	$ 975,000
2. Adsorbent Cost	45,000	90,000	225,000
	$ 420,000	$ 655,000	$1,200,000
B. Annual Operating Cost			
1. Adsorbent Makeup ($7/lb) (estimated life 8 years)	6,000	12,000	30,000
2. Steam (based on 20 bed volumes of steam condensate)	10,400	20,800	52,000
3. Electricity			
$0.03/kwh	3,800	7,500	18,800
0.06/kwh	7,500	15,000	37,500
0.09/kwh	11,300	22,500	56,300
0.12/kwh	15,000	30,000	75,000
4. Solvent	500	1,000	2,500
5. Maintenance 3% of Equipment Cost	12,600	19,700	36,000
6. Operators	20,000	20,000	20,000
7. Quality Control	9,000	9,000	9,000
8. Amortization (CRF 0.10185) (8% interest for 20 years)	42,800	66,700	122,200
Total Annual Cost			
$0.03/kwh	$ 105,100	$ 156,700	$ 290,500
0.06/kwh	108,800	164,200	309,200
0.09/kwh	112,600	171,700	328,000
0.12/kwh	116,300	179,200	346,700
Cost per 1000 gal treated			
$0.03/kwh	$0.288	$0.215	$0.159
0.06/kwh	0.298	0.225	0.169
0.09/kwh	0.308	0.235	0.180
0.12/kwh	0.319	0.245	0.190

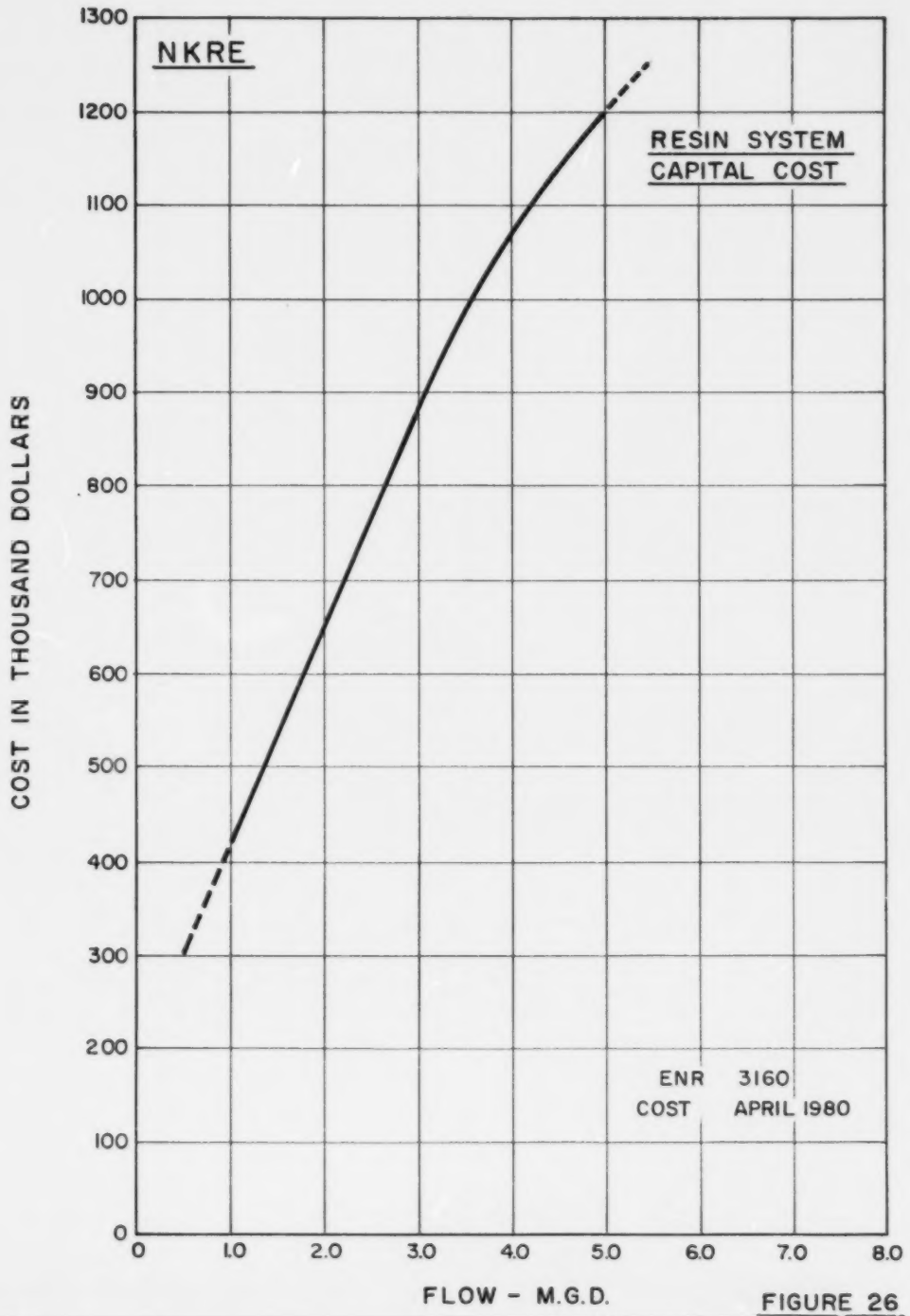
NKRE
RESIN SYSTEM
CAPITAL COST
COST IN THOUSAND DOLLARS
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
FLOW - M.G.D.
ENR 3160
COST APRIL 1980

FIGURE 26

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NKRE

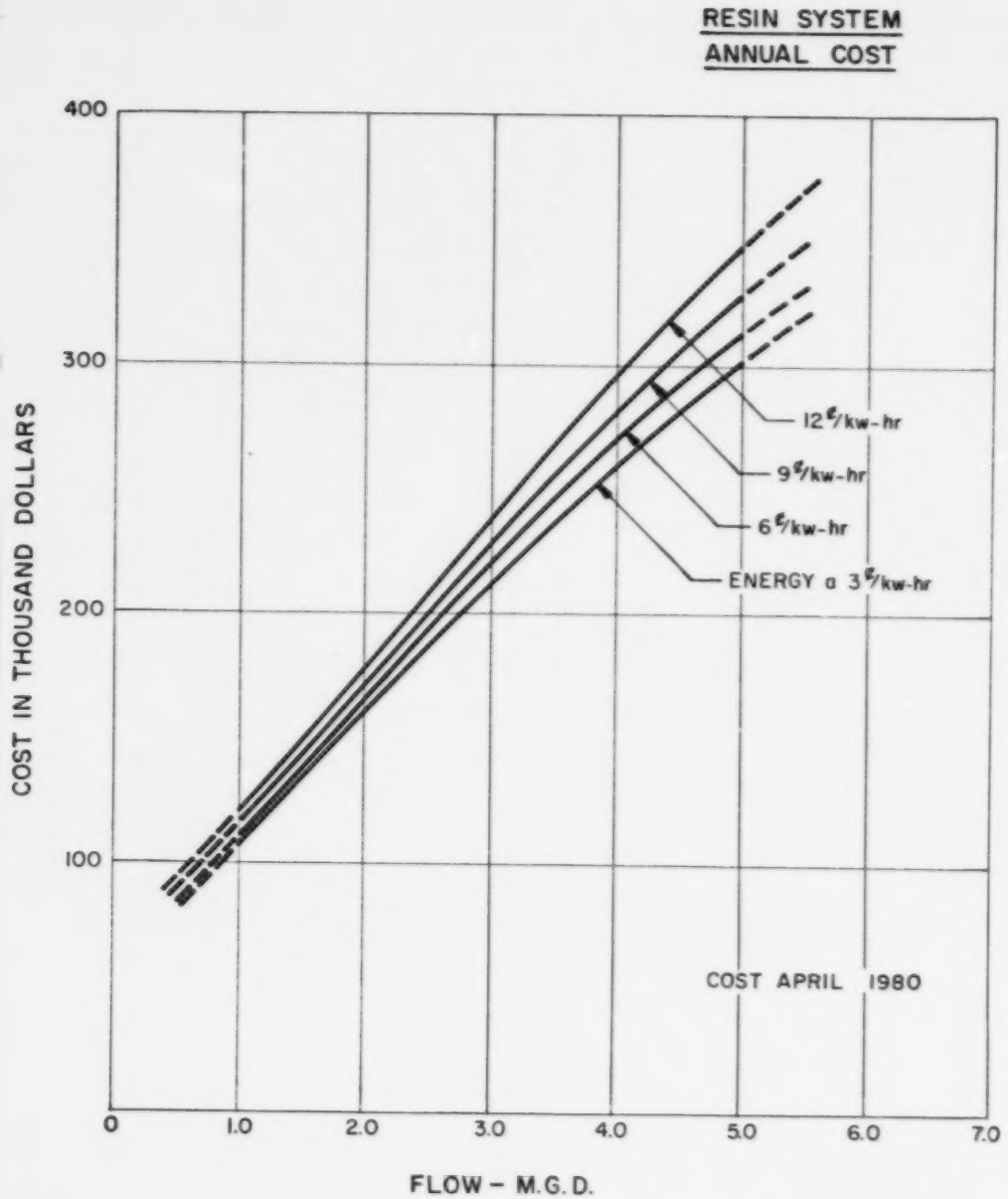

FIGURE 27

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NKRE

RESIN SYSTEM
ANNUAL COST
PER THOUSAND
GALLONS TREATED

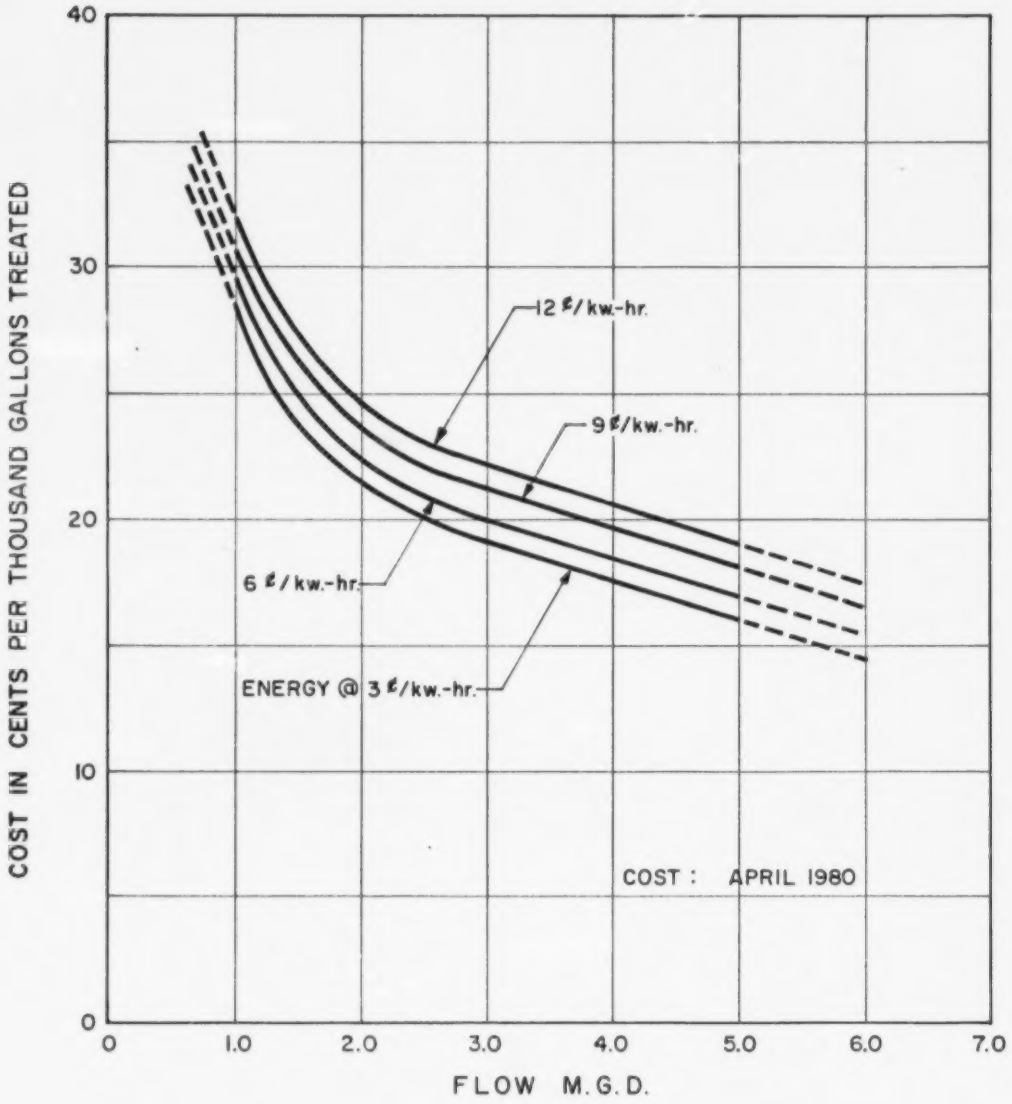

FIGURE 28

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APPENDIX A

ANALYTICAL PROCEDURE AND OPERATIONS

As part of the testing program at Glen Cove, NKRE agreed to perform the analyses of the samples for halogenated hydrocarbons. For this purpose, a Tekmar LSC-1 sample concentrator and Tracor 560 gas chromatograph equipped with a 700A Hall electrolytic conductivity detector and mini-integrator with digital printer were purchased. This equipment was assembled and installed by a Tracor representative.

The analytical procedure followed was that specified by MERL "Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants" (2).

Standards were prepared by volume rather than by mass, a mutually agreeable deviation from the procedure. Tekmar recommended a purging time of 11 minutes, and this time was used throughout. Variations were made in the program for the gas chromatograph in order to effect better separation between cis-1,2-dichloroethylene and 1,1,1-trichloroethane.

Initially, cis-1,2-dichloroethylene, trichloroethylene and tetrachloroethylene concentrations were determined. Later 1,1,1-trichloroethane was observed from the chromatogram and added to the list. The most pure trichloroethylene and tetrachloroethylene available were purchased from Aldrich Chemicals, and used as standard solutions. Their assays list them as 98% and 99^{+}% pure, respectively. Cis-1,2-dichloroethylene no longer is being manufactured in the United States in high purity. However, Chem Tech Research, Inc., of Hayward, California, still had in stock 95^{+}% pure cis-1,2-dichloroethylene, 50 g of which was purchased. The standard for 1,1,1-trichloroethane was supplied by MERL. The solvent used for preparing the standards is pesticide or HPLC grade methanol.

An independent quality assurance standard was prepared. It was analyzed ten times to determine the concentrations of its three main constituents (cis-1,2-dichloroethylene, trichloroethylene and tetrachloroethylene) and their respective standard deviations. Quality control charts, having limits of $\pm$ 2 standard deviations were then constructed. For the first few weeks of operation, this quality assurance sample was tested every other day. Later, testing was reduced to semi-weekly and eventually to weekly checks. Occasionally, samples

that were analyzed in this laboratory also were analyzed at MERL in Cincinnati or for Nassau County at Stonybrook, L.I. (SUNY). In addition, special control samples were prepared for this field work which contained only the four pollutants found in the well water. These also served as a check of the accuracy of the laboratory analyses.

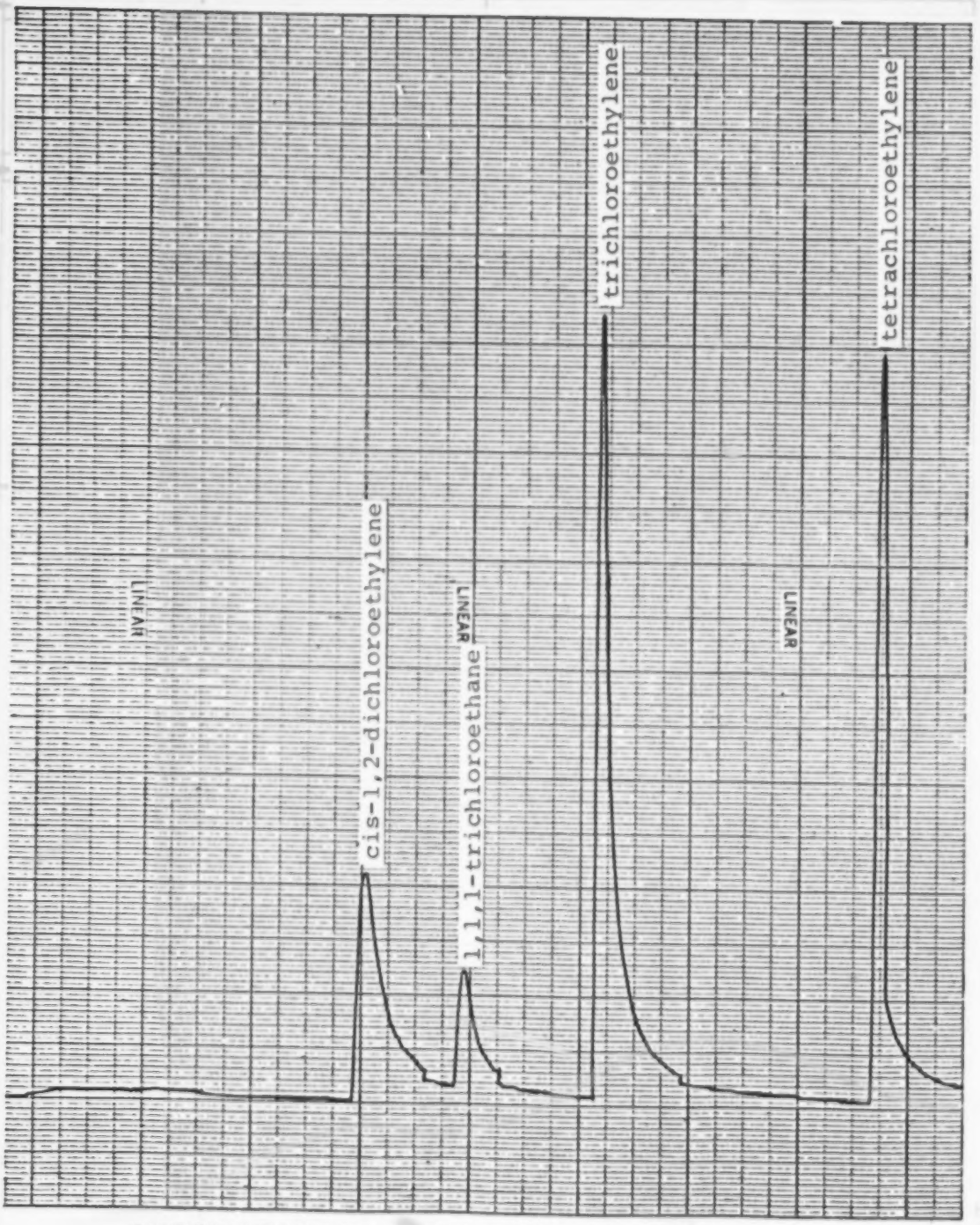
Before the pilot plant was officially started, there were continuing problems in the analytical system. The variety and frequency of these breakdowns produced a huge backlog of samples to be analyzed. In the first five months, the analytical system was inoperative more than 50% of the time. Problems included failure of the temperature regulation system in the gas chromatograph (three times) which required replacement of circuit boards, failure of the concentrator trap's heating mantle (twice), clogging of the Hall detector cell (three times), leaking in the detector base at a metal weld, deterioration of the chromatographic column (twice), and deterioration of the concentrator's trap.

Towards the end of August, a Tracor repairman spent two days resolving one or more of these problems. In addition to making certain repairs, he drastically shortened the line connecting the concentrator to the gas chromatograph and wrapped it with paper towelling for moderate insulation. No problems occurred after that which could not be handled by NKRE's analyst. Because the sensitivity of the gas chromatograph varied from day to day, appropriate standards were analyzed daily. The areas of the peaks of the standard had to be within a factor of two (-50%, +100%) of the areas of the samples being analyzed. If the sample fell outside the standard's range, a different standard was used. Calculation of the concentration assumed a linear relationship within the concentration range involved, where C = concentration and A = area:

$$C_{sample} = C_{standard} \, (A_{sample}/A_{standard})$$

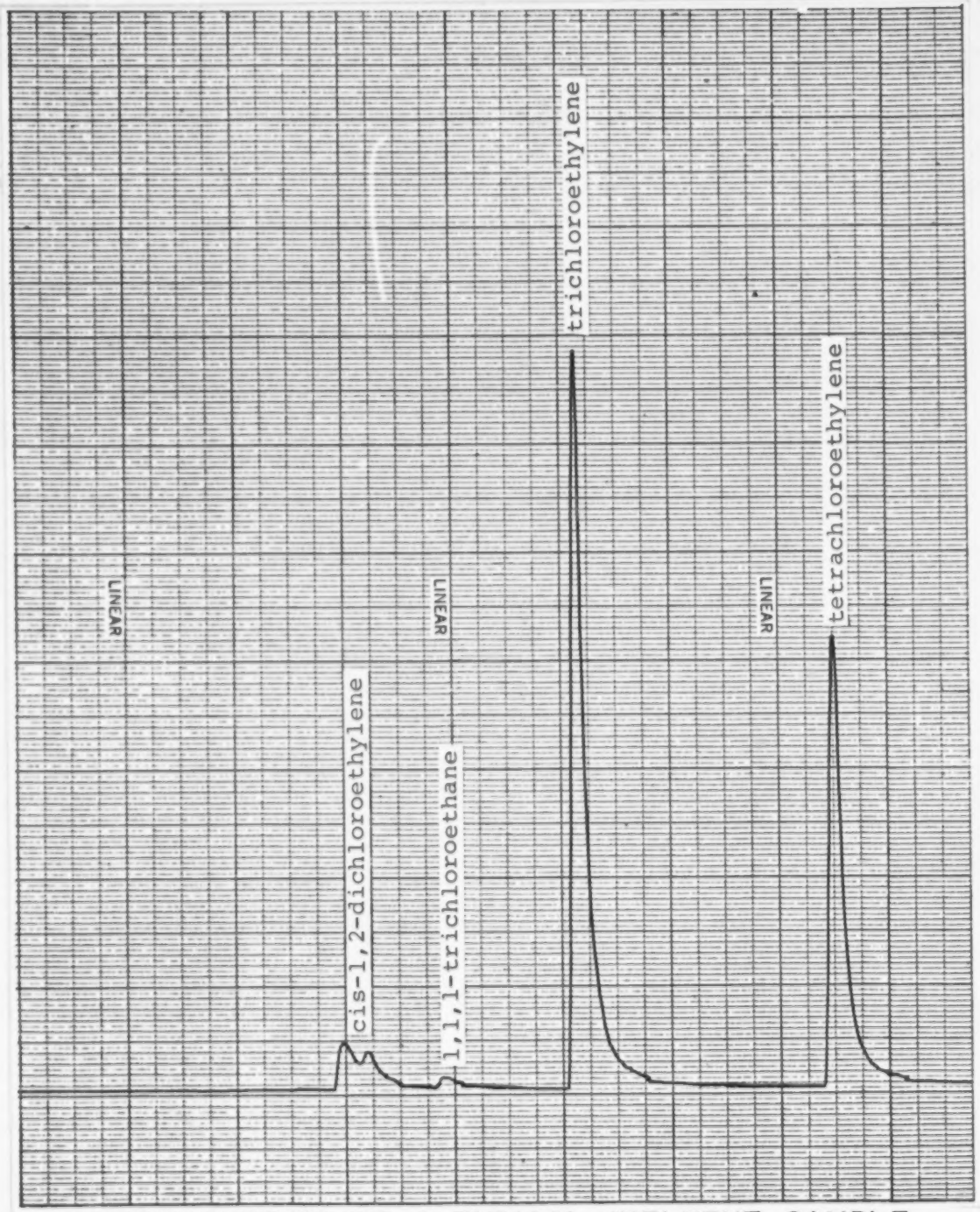
Towards the end of this phase of the pilot plant operation, when there was no backlog of samples and the concentrations of the various column effluents covered a wide range, a number of standards had to be used in one day covering a concentration range from one to more than fifty ug/l for the major contaminants. When the area of a sample fell between the areas of two of these standards, the concentration of the sample was determined by interpolation. In general, the multiple standards have shown that trichloroethylene and tetrachloroethylene are fairly linear throughout the range in question. This cannot be said of cis-1,2-dichloroethylene and 1,1,1-trichloroethane.

Figures A-1 and A-2 show typical chromatograms of a standard used in this work, and a typical influent sample.



CHROMATOGRAM OF A TYPICAL STANDARD

FIGURE A-1



CHROMATOGRAM OF A TYPICAL INFLUENT SAMPLE

FIGURE A-2

TABLE A-1

GAS CHROMATOGRAPH AND CONCENTRATOR

SETTINGS USED FOR ANALYSES

Monitor controls		1	250
		2	0
		3	200
		4	0
Oven Program		Initial Temperature	40°C
		Final Temperature	170°C
		Program Rate	8°/min.
		Initial Hold	4 min.
		Final Hold	6 min.
Detector		Solvent Flow	3.7
		Reactor Temperature	824°C
Gas Flows	(1)	He - cold (R.T.)	3.0
		- hot (170)	2.4
	(3)	H_2	20
Gas Regulators		He	62 lb/in^2 (427.49 kPa)
		H_2	44
Tekmar		He Flow	18
		Purge Time	11 min.
		Desorb. Temp.	200°C
		Trap Bake Temp.	250°C

APPENDIX B

TABLE B-1. PILOT PLANT RESULTS AT GLEN COVE, N.Y.
(All concentrations in ug/l)

Sample Day	Days of Operation	Date	Sample	cis	1,1,1	Tri	Tetra	
1	4	03-28-79	INF-1	3.6		10.1	2.8	
			I-RCE-1	NM	0.2	0.7	0.3	
			II-RCE-1	NM	0.1	0.5	0.2	
			III-RCE-1	NM	0.2	0.5	0.2	
			ACE-1	0.2		0.7	0.1	Air:Water:30:1
2	5	03-29-79	INF-2	24.1		52.0	22.5	
			I-RCE-2	NM	0.1	0.5	0.2	
			II-RCE-2	NM	0.2	0.5	0.2	
			III-RCE-2	NM	0.3	0.6	0.2	
			ACE-2	2.0		5.1	1.3	
3	6	03-30-79	INF-3	32.5		86.3	24.8	
			I-RCE-3	NM	0.1	0.3	0.1	
			II-RCE-3	NM	0.3	0.6	0.3	
			III-RCE-3	NM	0.2	0.6	0.1	
4	9	04-02-79	INF-4	58.8		138	41.4	
			I-RCE-4	NM	0.1	0.4	0.1	
			II-RCE-4	NM	0.1	0.4	0.1	
			III-RCE-4	NM	0.1	0.5	0.1	
			ACE-4	11.2		15.9	2.0	
5	10	04-03-79	INF-5	62.4		150	30.2	
			I-RCE-5	0.4	0.1	0.5	0.3	
			II-RCE-5	0.2	0.1	0.4	0.3	
			III-RCE-5	0.2	0.1	0.5	0.3	
			ACE-5	14.0		19.2	2.9	
6	11	04-04-79	INF-6	67.3		162	42.1	
			I-RCE-6	NM		1.1	NM	
			II-RCE-6	NM	NM	0.0	0.0	
			III-RCE-6	NM	0.1	0.5	0.1	
			ACE-6	2.0		12.7	2.1*	
7	12	04-05-79	INF-7	73.3		188	43.3	
			I-RCE-7	NM	0.4	0.5	0.2	
			II-RCE-7	NM	0.1	0.5	0.2	
			III-RCE-7	NM	0.1	0.4	0.2	
			ACE-7	2.7		14.7	2.4*	
8	13	04-06-79	INF-8	88.4		257	38.2	
			I-RCE-8	NM	0.2	0.5	0.1	
			II-RCE-8	NM	0.2	0.4	0.1	
			III-RCE-8	NM	0.1	0.5	0.1	
			ACE-8	2.0*		16.0	lost	

(Cont'd)

* Sample area differed from standards by factors of up to 2.8.

TABLE B1 (Continued)

Sample Day	Days of Operation	Date	Sample	cis	1,1,1	Tri	Tetra	
9	16	04-09-79	INF-9	98.2		231	44.1	
			I-RCE-9	NM	0.3	0.6	0.1	
			II-RCE-9	NM	0.2	0.6	0.1	
			III-RCE-9	NM	0.1	0.5	0.1	
			ACE-9	19.9		30.3	3.0	
10	17	04-10-79	INF-10	94.7		244	40.8	
			I-RCE-10	0.2		0.8	0.1	
			II-RCE-10	0.7		0.9	0.7	
			III-RCE-10	0.2		0.5	0.2	
			ACE-10	17.2		25.0	2.7	
11	18	04-11-79	INF-11	118		313	92.4*	
			I-RCE-11	0.4		1.0	0.3	Large late peak
			II-RCE-11	0.3		0.8	0.2	" " "
			III-RCE-11	0.3		0.8	0.2	late peak
			ACE-11	18.7		30.8	4.4	
12	19	04-12-79	INF-12	88.7		265	66.2*	
			I-RCE-12	1.7		1.2	0.5	
			II-RCE-12	0.7		0.8	0. 2	
			III-RCE-12	0.1		0.7	0.4	Huge late peak
			ACE-12	11.2		28.9	3.8	
13	20	04-13-79	INF-13	75.3		305	62.8*	
			I-RCE-13	0.4		0.5	0.2	
			II-RCE-13	0.3		0.7	0.4	Large late peak
			III-RCE-13	0.1		0.7	0.3	Large late peak
			ACE-13	23.8		22.9	0.9	
14	23	04-16-79	INF-14	47.2		170	25.0	
			I-RCE-14	0.9		0.9	0.9	
			II-RCE-14	0.1		0.7	0.2	
			III-RCE-14	0.2		0.6	0.4	
			ACE-14	11.7		29.1	2.4	Air:Water - 20:1
15	24	04-17-79	INF-15	39.7		157	17.9	
			I-RCE-15	0.5		0.7	0.2	
			II-RCE-15	NM		0.7	0.2	
			III-RCE-15	NM	0.1	0.6	0.1	
			ACE-15	11.0		26.3	4.3	
16	25	04-18-79	INF-16	36.5		140	19.2	
			I-RCE-16	0.5		0.8	0.2	
			II-RCE-16**	0.2		0.9	0.2	
			III-RCE-16	NM	0.1	0.6	0.1	
			ACE-16	18.4	0.4	42.3	3.4	

(Cont'd)

* These anomalously high results may be due to difficulties with the standard.
** Part of sample leaked out of sparging cell. Data prorated from second run peak for Tri.

TABLE B1 (Continued)

Sample Day	Days of Operation	Date	Sample	cis	1,1,1	Tri	Tetra
17	26	04-19-79	INF-17	35.2		135	22.8
			I-RCE-17	0.6		0.8	0.2
			II-RCE-17	NM	0.2	0.4	0.1
			III-RCE-17	NM	0.1	0.5	0.1
			ACE-17	19.7	1.1	47.7	3.3
18	27	04-20-79	INF-18	34.5		132	20.2
			I-RCE-18	0.3		0.9	0.2
			II-RCE-18	NM	0.1	0.4	0.1
			III-RCE-18	NM	0.1	0.4	0.1
			ACE-18	18.7	1.1	44.8	3.9
19	28	04-23-79	INF-19	54.6		212	33.6
			I-RCE-19	0.5	0.3	0.5	0.1
			II-RCE-19	NM	0.1	0.4	0.1
			III-RCE-19	NM	0.1	0.4	0.1
			ACE-19	16.2	1.0	41.0	3.8
20	29	04-24-79	INF-20	61.2		218	40.9
			I-RCE-20	1.0	0.6	0.4	0.1
			II-RCE-20	0.4	0.1	0.4	0.1
			III-RCE-20	0.2	0.1	0.3	0.1
			ACE-20	22.4	1.3	44.3	3.8
21	30	04-25-79	INF-21	58.6		265	38.5
			I-RCE-21	1.0	0.6	0.5	0.1
			II-RCE-21	0.1	0.0	0.4	0.1
			III-RCE-21	NM	0.1	0.4	0.1
			ACE-21	15.6	0.8	41.5	3.3
22	31	04-26-79	INF-22	56.1		215	35.0
			I-RCE-22	1.3	0.6	0.4	0.1
			II-RCE-22	0.1	0.1	0.5	0.1
			III-RCE-22	NM		0.9	NM
			ACE-22	13.7		29.4	2.1
23	32	04-27-79	INF-23	45.9		208	29.6
			I-RCE-23	1.5	0.6	0.5	0.1
			II-RCE-23	NM	0.1	0.4	0.1
			III-RCE-23	NM		0.2	NM
			ACE-23	15.6		32.3	1.8
24	33	04-30-79	INF-24	47.3		204	34.6
			I-RCE-24	NM		0.3	0.0
			II-RCE-24	0.1		0.3	1.0
			III-RCE-24	NM		0.1	0.0
			ACE-24	16.4		40.2	3.3

(Cont'd)

TABLE B1 (Continued)

Sample Day	Days of Operation	Date	Sample	cis	1,1,1	Tri	Tetra
25	34	05-01-79	INF-25	39.5		190	26.5
			I-RCE-25	NM		0.4	0.0
			II-RCE-25	NM		0.5	0.1
			III-RCE-25	0.0		0.1	0.1
			ACE-25	Sample froze - lost - no results			
26	35	05-02-79	INF-26	41.9		203	29.9
			I-RCE-26	2.4		1.5	NM
			II-RCE-26	NM		0.2	NM
			III-RCE-26	0.0		0.6	0.1
			ACE-26	17.5		39.8	3.9
27	36	05-03-79	INF-27	41.3		224	32.3
			I-RCE-27	2.8		1.6	0.2
			II-RCE-27	NM		0.5	NM
			III-RCE-27	NM		0.8	NM
			ACE-27	16.4		47.1	2.9
28	37	05-04-79	INF-28	43.3		207	28.5
			I-RCE-28	2.8		1.0	1.8
			II-RCE-28	1.2		0.5	0.0
			III-RCE-28	1.2		0.5	0.1
			ACE-28	12.2	0.5	38.1	2.7
29	40	05-07-79	INF-29	32.0		183	33.5
			I-RCE-29	<2		0.9	<1
			II-RCE-29	<2		0.9	<1
			III-RCE-29	NM		1.3	0.7
			ACE-29	11.2	0.5	37.0	3.3
30	41	05-08-79	INF-30	31.0		179	36.0
			I-RCE-30	2.1		0.7	0.0
			II-RCE-30	0.7		0.2	NM
			III-RCE-30	0.8		0.9	0.8
			ACE-30	10.6	0.6	38.7	3.0
31	42	05-09-79	INF-31	42.0		218	41.6
			I-RCE-31	NM		1.0	NM
			II-RCE-31	NM		0.7	0.8
			III-RCE-31	NM		0.8	0.1
			ACE-31	9.8	0.6	35.9	3.1
32	43	05-10-79	INF-32	39.4		194	35.6
			I-RCE-32	1.4		1.7	0.0
			II-RCE-32	1.0		0.5	0.2
			III-RCE-32	0.3		0.6	0.3
			ACE-32	9.4	0.5	36.3	2.6

(Cont'd

TABLE B1 (Continued)

Sample Day	Days of Operation	Date	Sample	cis	1,1,1	Tri	Tetra	
33	44	05-11-79	INF-33	40.4		221	49.9	
			I-RCE-33	28.7		2.3	0.0	
			II-RCE-33	0.4		0.8	0.1	
			III-RCE-33	NM		0.3	0.5	
			ACE-33	8.5	0.5	35.5	2.3	
34	48	05-15-79	INF-34	43.7		244	47.2	
			I-RCE-34	1.4		1.5	0.4	
			II-RCE-34	1.0		0.8	0.1	
			III-RCE-34	NM		1.4	0.4	
35	50	05-17-79	INF-35	35.9		247	52.9	
			I-RCE-35	4.3		1.3	0.0	
			II-RCE-35	<0.5		0.7	0.1	
			III-RCE-35	<0.5		0.8	NM	
			ACE-35	7.0	0.4	31.0	2.0	
36	55	05-22-79	INF-36	26.9		252	55.0	
			I-RCE-36	5.9		2.2	0.0	
			II-RCE-36	NM		1.3	NM	
			III-RCE-36	1.2		0.4	0.0	
			ACE-36	6.9	0.3	30.0	2.4	
37	57	05-24-79	INF-37	24.9		221	39.7	
			ACE-37	6.6	0.4	33.4	2.7	
38	58	05-25-79	INF-38	25.4		228	40.9	
			I-RCE-38	9.8		1.1	1.7	
			II-RCE-38	NM		0.9	0.9	
			III-RCE-38	1.0		0.6	0.3	
39	62	05-29-79	INF-39	22.6		218	38.5	
			I-RCE-39	13.4		2.7	0.8	
			II-RCE-39	0.9		0.9	NM	
			III-RCE-39	NM		0.7	NM	
			ACE-39	6.8	0.3	34.0	2.8	
40	64	05-31-79	INF-40	24.7		227	36.6	
			I-RCE-40	20.8	1.4	1.6	0.7	
			II-RCE-40	NM		0.4	0.0	
			III-RCE-40	NM		0.4	0.1	
			ACE-40	7.0	0.4	33.6	2.6	
41	69	06-05-79	INF-41	Septum reversed - results erroneous				
			I-RCE-41	26.8	1.1	3.3	1.1	
			II-RCE-41	0.1	0.3	0.9	0.4	
			III-RCE-41	NM	0.1	0.8	0.2	
			ACE-41	6.8	0.4	34.7	2.7	(Cont'd)

TABLE B1 (Continued)

Sample Day	Days of Operation	Date	Sample	cis	1,1,1	Tri	Tetra	
42	72	06-08-79	INF-42	18.4		191	41.4	
			I-RCE-42	39.1	0.2	5.0	1.4	
			II-RCE-42	0.3	0.2	0.9	0.1	
			III-RCE-42	NM	0.1	0.8	0.1	
			ACE-42	6.2	0.6	36.0	3.2	
43	77	06-13-79	INF-43	30.9		185	34.6	
			I-RCE-43	40.2	1.6	5.9	1.5	
			II-RCE-43	0.2	0.3	0.9	0.2	
			III-RCE-43	NM	0.1	0.7	0.1	
			ACE-43	6.3	0.5	33.2	3.4	
44	83	06-19-79	INF-44	31.9		197	53.9	
			I-RCE-44	43.8	1.7	6.8	0.8	
			II-RCE-44	NM	0.5	1.0	0.1	
			III-RCE-44	NM	0.3	1.1	0.1	
			ACE-44	5.9	0.4	33.9	3.3	
45	85	06-21-79	INF-45	25.9		192	42.1	
			I-RCE-45	36.0	1.3	2.7	0.5	
			II-RCE-45	0.1	0.1	0.6	0.2	
			III-RCE-45	NM	0.1	0.4	0.2	
			ACE-45	6.6	0.5	35.7	3.6	
46	89	06-25-79	INF-46A	31.2	3.2	235	33.7	10:53 AM
				not tested	4.0	210	30	11:15 AM*
				not tested	4.0	210	33	11:45 AM*
			INF-46B	28.1	2.9	230	41.9	12:55 PM
			INF-46C	31.0	3.1	244	61.4	2:50 PM
47	90	06-26-79	INF-46D	26.5	2.7	198	37.7	1:00 PM
48	91	06-27-79	INF-46E	31.5		229	41.2	10:00 AM
		06-27-79	INF-47	26.6	2.9	225	35.9	2:10 PM
			I-RCE-47	21.0**		12.4	1.0	
			II-RCE-47	1.3		1.4	0.1	
			III-RCE-47	NM	0.1	0.5	0.2	
			IV-RCE-47	0.7		0.3	0.1	
			ACE-47	4.3	0.3	28.2	3.5	
49	92	06-28-79	INF-48	27.2	2.8	228	39.6	
			I-RCE-48	22.4**		8.0	0.5	
			IV-RCE-48	NM		0.2	0.1	(Cont'd)

* Nassau Co. Dept. of Health Analyzed.

** For I-RCE's value given is the total for Cis-$C_2H_2Cl_2$ and 1,1,1-$C_2H_3Cl_3$.

TABLE B1 (Continued)

Sample Day	Days of Operation	Date	Sample	cis	1,1,1	Tri	Tetra	
50	93	06-29-79	INF-49	26.7	3.1	217	43.6	
			I-RCE-49	26.6*		9.5	0.4	
			II-RCE-49	1.3		1.8	0.1	
			III-RCE-49	NM	0.4	0.7	NM	
			IV-RCE-49	NM		0.2	NM	
			ACE-49	4.5	0.5	27.8	3.2	
51	96	07-02-79	INF-50	35.6	5.6	218	64.6	
			I-RCE-50	28.0*		11.4	0.5	
			IV-RCE-50	1.6		0.7	NM	
52	97	07-03-79	INF-51	29.9	3.9	170	28.6	
			I-RCE-51	26.0*		8.3	0.9	
			II-RCE-51	NM		1.2	0.0	
			III-RCE-51	1.8		1.0	NM	
			IV-RCE-51	1.1		1.2	NM	
			ACE-51	4.0	NM	25.8	2.7	
53	98	07-05-79	INF-52	35.2	5.4	207	47.5	
			I-RCE-52	28.3*		8.7	0.8	
			IV-RCE-52	4.1		1.5	0.2	
54	99	07-06-79	INF-53	33.5	4.7	205	40.0	
			I-RCE-53	27.7*		9.7	1.0	
			II-RCE-53	0.5	1.0	0.3	NM	
			III-RCE-53	NM	0.5	0.6	0.2	
			IV-RCE-53	1.0		0.2	0.1	
			ACE-53	3.9	0.2	23.2	5.0	
55	102	07-09-79	INF-54	34.2	5.7	206	51.5	
			I-RCE-54	31.4*		10.8	1.3	
			IV-RCE-54	2.9		1.4	NM	
56	103	07-10-79	INF-55	33.9	5.0	202	46.1	
			I-RCE-55	35.0*		12.4	1.5	
			II-RCE-55	0.7	1.0	0.6	NM	
			III-RCE-55	NM	NM	0.3	NM	
			IV-RCE-55	5.3		0.4	NM	
			ACE-55	8.4	0.6	32.6	4.5	
57	104	07-11-79	INF-56	34.0	4.7	200	44.3	
			I-RCE-56	31.9*		11.0	1.4	
			IV-RCE-56	1.7		1.9	0.1	
58	105	07-12-79	INF-57	33.2	5.0	196	75.5	
			I-RCE-57	32.7	1.4	16.1	1.7	
			IV-RCE-57	1.7	0.9	0.8	0.1	(Cont'd)

* Value given is the total for Cis-$C_2H_2Cl_2$ and 1,1,1-$C_2H_3Cl_3$.

TABLE B1 (Continued)

Sample Day	Days of Operation	Date	Sample	cis	1,1,1	Tri	Tetra	
59	106	07-13-79	INF-58	41.4	5.1	191	45.0	
			I-RCE-58	33.4	1.7	16.3	1.9	
			II-RCE-58	0.7	0.2	0.4	NM	
			III-RCE-58	0.5	0.4	0.8	0.1	
			IV-RCE-58	2.2	0.8	0.8	0.3	
			ACE-58	9.0	0.6	33.5	4.9	
60	113	07-20-79	INF-59	47.5	5.4	198	52.5	
			I-RCE-59	30.0	1.6	13.8	1.9	
			II-RCE-59	19.7	1.0	12.0	1.0	
			III-RCE-59	11.9	0.5	3.0	0.2	
			IV-RCE-59	4.2	0.4	0.7	0.2	
			ACE-59	8.6	0.6	34.0	4.4	
61	117	07-24-79	INF-60	49.1	6.2	213	57.7	
			I-RCE-60	22.2	1.9	19.4	2.7	
			II-RCE-60	22.9	1.1	10.9	1.8	
			III-RCE-60	13.5	0.5	3.2	0.1	
			IV-RCE-60	3.9	0.3	0.7	0.1	
			ACE-60	10.3	0.8	36.1	5.2	
62	127	08-03-79	INF-61	48.3	5.8	206	61.7	
			I-RCE-61	47.1	2.4	29.1	5.1	
			II-RCE-61	25.6	1.3	8.7	0.8	
			III-RCE-61	11.5	0.6	3.6	0.2	
			ACE-61	8.6	0.6	34.0	5.1	
63	137	08-13-79	INF-62	52.4	6.3	219	56.8	
			II-RCE-62	27.0	1.2	13.0	1.5	
			III-RCE-62	15.1	0.7	7.3	0.5	
			IV-RCE-62	5.9	0.5	4.0	0.5	
			ACE-62	9.8	0.8	35.8	6.0	
64	147	08-23-79	INF-63	39.6	7.6	233	71.2	
			I-RCE-63	NM	0.6	19.0	3.5	
			II-RCE-63	31.3	1.1	13.9	1.1	
			III-RCE-63	12.6	0.6	7.9	0.4	
			IV-RCE-63	14.7	1.0	14.4	1.5	
			ACE-63	11.0	0.8	34.3	6.6	
65	148	08-24-79	INF-64	65.0	6.0	213	67.4	
			I-RCE-64	0.7	0.3	2.6	0.8	
			IV-RCE-64	14.4	0.8	14.4	1.4	
66	151	08-27-79	INF-65	61.4	5.7	209	57.8	
			I-RCE-65	0.8	1.0	4.7	2.3	
			II-RCE-65	32.5	1.0	14.7	1.0	
			III-RCE-65	13.7	0.9	10.4	0.6	
			IV-RCE-65	14.6	1.3	1.8	2.4	
			ACE-65	9.0	0.7	33.6	6.6	(Cont'd)

TABLE B1 (Continued)

Sample Day	Days of Operation	Date	Sample	cis	1,1,1	Tri	Tetra
67	152	08-28-79	INF-66	37.0	5.8	201	62.1
			I-RCE-66	1.3	0.7	3.9	2.0
68	153	08-29-79	INF-67	35.7	5.5	197	86.9
			I-RCE-67	1.5	0.9	3.3	1.9
69	154	08-30-79	INF-68	36.8	5.2	190	75.4
			I-RCE-68	1.9	1.0	4.0	2.6
70	155	08-31-79	INF-69	35.0	5.1	189	69.9
			I-RCE-69	2.2	1.0	3.0	2.0
			II-RCE-69	33.8	0.9	16.6	1.0
			III-RCE-69	14.9	0.7	12.3	0.6
			IV-RCE-69	15.7	1.6	9.5	1.9
			ACE-69	4.3	0.2	25.4	4.4
71	159	09-04-79	INF-70	35.2	5.1	198	60.9
			I-RCE-70	3.3	1.4	7.3	2.7
72	160	09-05-79	INF-71	33.2	4.9	193	54.1
			I-RCE-71	4.4	1.5	7.0	4.6
73	161	09-06-79	INF-72	32.9	5.1	187	44.1
			I-RCE-72	4.4	2.0	5.6	3.6
			II-RCE-72	37.7	1.0	26.4	1.8
			III-RCE-72	18.0	0.5	20.2	1.0
			IV-RCE-72	20.3	2.0	13.4	3.4
74	169	09-14-79	INF-73	35.0	5.1	199	66.9
			I-RCE-73	7.6	2.1	9.4	6.7
			II-RCE-73	39.9	1.0	30.8	2.0
			III-RCE-73	19.8	0.5	24.5	1.8
			IV-RCE-73	23.2	2.1	17.6	8.2
			ACE-73	6.2	0.4	36.3	8.7
75	173	09-18-79	II-RCE*	34.6	NM	27.9	2.1
			Town water	NM	NM	0.7	0.1
76	176	09-21-79	INF-74	31.3	4.1	210	71.8
			I-RCE-74	9.3	1.6	16.2	6.3
			II-RCE-74	25.3	0.8	13.4	1.5
			III-RCE-74	14.9	0.4	7.1	0.4
			IV-RCE-74	17.9	2.1	18.1	4.8
			ACE-74	5.5	0.5	32.9	6.7

(Cont'd)

* Analyzed by U.S. EPA's MERL Laboratory, Cincinnati.

TABLE B1 (Continued)

Sample Day	Days of Operation	Date	Sample	cis	1,1,1	Tri	Tetra	
77	183	09-28-79	INF-75	29.7	3.2	213	68.8	
			I-RCE-75	13.4	2.1	22.2	8.4	
			II-RCE-75	27.6	1.1	13.9	1.2	
			III-RCE-75	15.6	0.4	7.2	0.2	
			IV-RCE-75	21.9	2.5	23.2	6.5	
			ACE-75	8.2	0.4	38.8	8.7	
78	190	10-05-79	INF-76	32.7	3.7	207	72.0	
			I-RCE-76	16.5	2.4	25.6	8.9	
			II-RCE-76	31.7	1.4	15.9	1.5	
			III-RCE-76	13.8	0.3	6.7	0.2	
			IV-RCE-76	21.4	2.6	24.5	6.8	
			ACE-76	9.4	0.8	39.2	9.3	
79	197	10-12-79	INF-77	30.9	4.0	212	58.9	
			I-RCE-77	18.2	2.6	23.3	7.7	
			II-RCE-77	30.9	2.3	9.6	1.6	
			III-RCE-77	9.5	0.6	3.6	0.3	
			IV-RCE-77	23.5	3.3	24.2	6.7	
			ACE-77	7.4	1.2	33.7	6.6	
80	207	10-22-79	INF-78	31.0	3.9	221	67.5	
			I-RCE-78	15.3	1.3	14.6	3.5	
			II-RCE-78	32.6	1.6	15.9	1.8	
			III-RCE-78	13.1	0.3	10.5	4.1	
			IV-RCE-78	28.4	3.3	45.6	12.4	
			ACE-78	9.0	1.3	42.2	13.3	
81	213	10-29-79	INF-79	38.8	4.0	251	80.8	
			I-RCE-79	24.0	3.5	65.4	20.2	
			II-RCE-79	44.7	3.0	53.0	11.6	
			III-RCE-79	16.5	0.4	6.3	0.6	
			IV-RCE-79	24.7	3.5	34.9	5.9	
			ACE-79	13.4	0.9	65.4	21.6	Air:water = 15:1
82	214	10-30-79	I-RCE	24.0	2.5	65.8	18.7	
83	220	11-05-79	INF-80	40.0	4.3	238	73.6	
			III-RCE-80	18.1	NM	5.7	0.4	
			IV-RCE-80	48.6	5.1	51.1	10.3	
			ACE-80	15.4	0.6	62.4	13.4	
84	221	11-06-79	INF-81	51.8	6.1	286	88.3	
			II-RCE-81	NM	NM	0.8	0.4	
85	222	11-07-79	INF-82	52.3	6.5	285	89.1	
			II-RCE-82	NM	NM	0.9	0.4	

(Cont'd)

TABLE B1 (Continued)

Sample Day	Days of Operation	Date	Sample	cis	1,1,1	Tri	Tetra	
86	227	11-12-79	INF-83	51.7	6.5	280	83.4	
			II-RCE-83	NM	NM	0.9	0.4	
			III-RCE-83	20.0	0.7	5.5	8.2	
			IV-RCE-83	51.9	3.7	34.8	8.0	
			ACE-83	9.7	0.5	38.7	15.8	
87	228	11-13-79	INF-84	52.2	4.9	193	80.5	
			II-RCE-84	NM	0.0	1.0	0.5	
88	229	11-14-79	INF-85	50.0	5.1	192	119	
			I-RCE-85	2.9	1.3	0.6	1.9	
			II-RCE-85	NM	0.0	1.5	10.9	
89	230	11-15-79	INF-86	50.7	4.7	196	80.9	
			I-RCE-86	3.8	1.8	1.7	6.9	
			II-RCE-86	NM	0.0	0.6	0.2	
90	231	11-16-79	INF-87	52.9	4.7	192	85.8	
			I-RCE-87	59.9	4.8	68.8	18.8	
			II-RCE-87	NM	0.4	0.6	0.2	
91	234	11-19-79	INF-88	62.3	6.1	213	113	
			I-RCE-88	6.0	2.0	6.3	10.1	
			II-RCE-88	NM	0.1	0.7	0.4	
			III-RCE-88	24.0	1.0	6.5	2.5	
			IV-RCE-88	58.3	3.8	66.5	18.4	
			ACE-88	14.3	1.5	43.7	14.5	
92	235	11-20-79	Well 21	13.0	1.9	116	56.5	
93	236	11-21-79	INF-89	54.6	4.7	190	94.7	
			I-RCE-89	7.0	1.5	8.4	12.0	
			II-RCE-89	NM	0.6	0.7	0.5	
94	238	11-23-79	INF-90	56.2	5.3	179	82.8	
			I-RCE-90	7.6	2.3	10.3	15.1	
			II-RCE-90	NM	0.2	0.6	0.3	
95	241	11-26-79	INF-91	61.2	5.6	178	94.3	
			I-RCE-91	9.3	2.6	13.7	15.5	
			II-RCE-91	NM	0.2	0.4	0.3	
			III-RCE-91	27.6	1.5	7.3	1.5	
			IV-RCE-91	62.6	4.9	72.1	19.9	
			ACE-91	10.6	0.8	38.2	11.2	(Cont'd)

TABLE B1 (Continued)

Sample Day	Days of Operation	Date	Sample	cis	1,1,1	Tri	Tetra	
96	243	11-28-79	INF-92	62.2	5.7	191	91.8	
			I-RCE-92	9.5	2.5	15.2	17.5	
97	251	12-06-79	INF-93	59.0	5.1	190	100	
			I-RCE-93	16.4	2.5	21.2	21.3	
			II-RCE-93	2.5	0.3	3.3	1.2	
			III-RCE-93	27.6	1.8	12.7	1.7	
			IV-RCE-93	57.3	3.9	58.8	14.4	
			ACE-93	9.0	0.8	33.2	12.8	
98	256	12-11-79	INF-94	58.3	4.9	175	95.9	
			I-RCE-94	27.4	3.5	32.4	27.5	
			II-RCE-94	5.4	1.2	8.8	3.9	
			III-RCE-94	32.8	1.9	11.3	1.5	
			IV-RCE-94	50.4	4.8	59.8	21.6	
			ACE-94	12.3	1.5	35.6	12.8	
99	257	12-12-79	INF	70.7	6.2	235	118	
100	263	12-18-79	INF-95	54.9	5.6	197	102	
			I-RCE-95	31.0	3.7	37.5	35.8	
			II-RCE-95	5.5	0.8	4.2	3.6	
			III-RCE-95	32.9	1.2	10.5	1.1	
			IV-RCE-95	51.2	5.2	93.4	29.7	
			ACE-95	17.3	1.1	46.3	18.2	Air:water = 5:1
101	271	12-27-79	INF-96	57.9	4.6	173	100	
			I-RCE-96	36.1	3.5	48.1	37.9	
			II-RCE-96	6.0	1.1	4.1	1.9	
			III-RCE-96	26.4	1.4	9.4	1.8	
			IV-RCE-96	62.9	5.1	103	34.0	
			ACE-96	25.1	1.8	61.5	26.7	
102	279	01-03-80	INF-97	61.7	5.0	171	99.8	
			I-RCE-97	37.7	4.1	47.9	38.1	
			II-RCE-97	6.2	1.1	4.1	1.4	
			III-RCE-97	33.6	2.1	11.0	2.4	
			IV-RCE-97	59.4	4.8	78.3	30.0	
			ACE-97	30.8	2.1	60.0	30.1	

TABLE B-2 - SUMMARY OF PILOT PLANT ANALYTICAL DATA - (A) RESIN ADSORPTION

Resin Column	Depth	Length of Run		Compound	Effluent Concentration (µg/l)		Breakthrough		Influent for Corresponding Period (after day 8 of initial start-up)		
		Days	Bed Volumes		Min.	Max.	Days	Bed Volumes	Min.	Max.	Ave.
I	1 ft.	129*	99.9×10^3*	cis	N.M.	47.1	48	37.2×10^3	18.4	118	40
				1,1,1	N.M.	2.4	-	-	2.8	6.2	5
				tri	0.3	29.1	108	83.7×10^3	132	313	215
				tetra	N.M.	5.1	-	-	17.9	92.4	41
		71	55.0×10^3	cis	N.M.	24.0	17	13.2×10^3	29.7	65.0	35
				1,1,1	0.3	3.5	-	-	3.2	7.6	4.5
				tri	2.6	65.8	25	19.4×10^3	187	251	210
				tetra	0.8	20.2	63	48.8×10^3	44.1	86.9	68
		49	38.0×10^3	cis	2.9	37.7**	3***	2.3×10^3***	50.0	70.7	58
				1,1,1	1.3	4.1**	"	"	4.6	6.2	5.2
				tri	0.6	48.1**	"	"	171	235	191
				tetra	1.9	38.1			80.9	119	98
II	2 ft.	210	81.3×10^3	cis	N.M.	44.7	102	39.5×10^3	18.4	118	38
				1,1,1	N.M.	3.0	-	-	2.8	7.6	5
				tri	0.0	53.0	203	78.6×10^3	132	31.3	210
				tetra	0.0	11.6	203	78.6×10^3	17.9	92.4	51
		57	44.2×10^3	cis	N.M.	6.2	-	-	50.0	70.7	57
				1,1,1	N.M.	1.2	-	-	4.6	6.5	5.4
				tri	0.4	8.8	-	-	171	286	206
				tetra	0.2	3.9	-	-	80.5	119	96
III	4 ft.	275	53.3×10^3	cis	N.M.	33.6	102	19.7×10^3	18.4	118	40
				1,1,1	0.3	2.1	203	39.3×10^3	2.8	7.6	5
				tri	0.2	24.5	-	-	132	313	210
				tetra	N.M.	8.2	-	-	17.9	119	65
IV	1 ft	189	146.0×10^3	cis	N.M.	62.9	47	36.4×10^3	26.6	70.7	40
				1,1,1	0.3	5.2	-	-	2.8	7.6	5
				tri	0.2	103	107	82.9×10^3	170	286	210
				tetra	N.M.	34.0	138	106.0×10^3	28.6	119	70

(Cont'd)

TABLE B-2 - SUMMARY OF PILOT PLANT ANALYTICAL DATA - (B) AERATION

Air/water Ratio	Compound	% Reduction			Influent Concentration (μg/1)			Effluent Concentration (μg/1)		
		Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.
30:1	cis	68.4	97.0	85	58.8	118	82.5	2.0	23.8	12.3
	1,1,1	-	-	-	-	-	-	-	-	-
	tri	86.9	93.8	90	138	313	225	12.7	30.8	21.6
	tetra	90.3	98.5	95	30.2	92.4	50.2	0.9	4.4	2.7
20:1	cis	44.0	88.4	75	18.4	61.2	40	3.9	19.7	10
	1,1,1	66.1	95.5	85	2.9	7.6	5	0.2	1.3	0.5
	tri	64.7	92.5	85	132	265	210	23.2	47.7	35
	tetra	75.8	96.3	92	17.9	72.0	52	1.8	13.3	3.5
15:1	cis	61.5	82.7	75	38.8	62.3	53.0	9.0	15.4	12.1
	1,1,1	69.9	93.0	82	4.1	6.5	5.2	0.5	1.5	0.9
	tri	73.8	86.2	78	175	280	218	33.2	65.4	45.3
	tetra	75.0	88.1	84	73.6	113	91.6	11.2	21.6	14.7
5:1	cis	50.1	68.5	58	54.9	61.7	58.2	17.3	30.8	24.4
	1,1,1	58.4	80.3	66	4.6	5.6	5.0	1.1	2.1	1.7
	tri	64.5	76.5	69	171	197	180	46.3	61.5	55.9
	tetra	69.8	82.2	75	99.8	102	101	18.2	30.1	25.0

Notes for Table I:

* A regeneration after 85 days (65.8×10^3 bed volumes) was unsuccessful.

** The sample taken after two days of operation showed anomalously high concentrations: 59.9, 4.78, 68.8 and 18.8 respectively for the four contaminants. As this seems related to the recent regeneration and not to the normal operation of the column, these figures were not listed.

*** The sample taken when this column was put back into line had low concentrations of contaminants (all are minimum values). The contaminants increased steadily with use. There was no base line period from which to judge the beginning of leakage. The choice of 3 therefore is somewhat arbitrary.

NM = Not measureable.

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APPENDIX C

Industrial Hygienics, Inc.

755 NEW YORK AVENUE, HUNTINGTON, NEW YORK 11743 • (516) 427-0950

March 5, 1980

RECEIVED
HYDROTECHNIC CORP.
MAR 10 1980
To

Dr. Robert Ausubel
Nebulsin, Kohlmann & Ruggierlo
1250 Broadway
New York, New York 10001

Dear Dr. Ausubel,

Enclosed is the information you requested concerning our work at the Glen Cove project. Much of it is redundant to the first report with further details included.

Sampling Method

As per the correspondence sent December 12, 1979 the air samples were collected according to NIOSH recommendations for organic solvents (NIOSH Analytical Methods, Method #P & CAM 127). Strategy was designed to establish a representative airborne concentration of the four analytes over the aeration column. The sampling pumps were positioned at right angles around the perimeter of the column.

Analytical Procedure

The analysis followed NIOSH analytical method P & CAM 127. Organic solvents are desorbed from charcoal tubes using carbon disulfide and then analyzed by gas chromatography. The components are identified by matching retention time with pure solvents.

There are no New York State limits for these substances in ambient air. However, standards do exist for the workroom environment. Perhaps these OSHA limits will be of interest in your report:

Substance	OSHA (TWA - 8 hr. period) ppm
1,1,1 - Trichloroethane	350
1,1, - 2 Trichloroethylene	100 (intended change - 50)
Tetrachloroethylene	100 (skin)
1,2 - Dichloroethane	50 (intended change - 10)

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In answer to your puzzlement over the report of 1,2 - dichloroethane, the retention time peak in our analysis matches that of 1,2 - dichloroethane. Further confirmation can be made only by gas chromatography/mass spectroscopy. At present, our laboratory is not equipped to offer that method of analysis.

Very truly yours,

James T. Schirripa, CIH, ABIH
President
Diplomate, AAIH

TABLE C-1

CONCENTRATIONS OF VARIOUS CHLORINATED HYDROCARBONS IN AIR (ABOVE AERATION COLUMN)

Sample #	1,1,1 Trichloroethane ppb	1,1,2 Trichloroethylene ppb	1,1,1,1 Tetrachloroethylene ppb	1,2 Dichloroethane ppb
102264-1	24.5	32.4	13.2	24.7
102260-1	13.7	2.5	4.0	18.75
102261-1	38.3	639.5	271.2	21.13
102269-1	41.5	166.8	53.0	21.88
Mean ($\bar{x}$)	29.5	201.3	85.3	21.6

NOTE: ppb = parts per billion (volume/volume)

APPENDIX D

Table D-1

Key to Chemical Symbols

$cis\text{-}C_2H_2Cl_2$	-	cis-1,2-Dichloroethylene
CH_3CCl_3	-	1,1,1-Trichloroethane
C_2HCl_3	-	Trichloroethylene
C_2Cl_4	-	Tetrachloroethylene

Table D-2

Conversion Table
(English to Metric Units)

feet	x	0.3048	=	meters
gallons	x	0.003785	=	cubic meters
gallons	x	3.785	=	liters
million gallons/ day	x	3.785	=	cubic meters/day
pounds	x	0.454	=	kilograms

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Refere es

1) Rohm & Haas Company, "Regenerability of Ambersorb XE-340" - Spring House, Pennsylvania, September, 1979.

2) U.S. Environmental Protection Agency, "Sampling and Analysis Procedures for Screening of Industrial Effluents Priority Pollutants". Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268, March, 1977, Revised April, 1977.

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